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ABSTRACT

A series of short courses was presented on various aspects of curriculum practice to enable teachers to review and reconsider established practices, to acquire knowledge of recent and impending developments, and to gain experience in the techniques involved. This collection of rewritten versions of lectures given at these classes is divided into two parts. Three sections in the first part focus on objectives, assessments, and activity-based learning situations, while the final section is an effort to reconcile the problems of preparing worthwhile objectives relating to transferable mental skills and personal qualities with the need to make valid assessments. The second part provides examples, based on teacher ideas and experiences, of activity-based teaching-learning situations demonstrating the implementation of the principles discussed. (Author/CMV)

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TEACHING AND LEARNING IN THE TEC ERA

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TEACHING AND LEARNING IN THE TEC ERA

INTRODUCTION

These notes are re-written versions of lectures given at a series of teachers' short courses, held under the sponsorship of the Welsh Joint Education Committee, which I have directed in the last three years. These courses have been concerned with impending changes in curriculum design and implementation arising from the work of the Technician Education Council. Most took place before TEC had issued many of its informational circulars and the interpretation of TEC policy was therefore a personal one. The content of these courses was mostly concerned with the teachers' contribution to curriculum processes since the organisational and management consequences of the changes arising as a result of TEC would be, and since then largely have been, either spelled out or implied by TEC and there was little point in anticipating those.

The changes or developments in teaching and learning strategies however could be properly anticipated since TEC policy in these aspects at curriculum process was not made ab initio. It has clearly grown out of the body of work, both practical and theoretical, which has been carried out and discussed over recent years. It was apparent very early that TEC had decided that the changes which it was to initiate should not take place without taking note of, and advantage of, the present stage of knowledge of educational systems and curriculum processes.

It was therefore apparent that there would be a need for teaching staff to review and reconsider established practices, to acquire knowledge of recent and impending developments and to gain experience in the techniques involved. The WJEC has therefore held teachers' courses on various aspects of curriculum practice such as objective writing, programme planning, learning resources, assessment techniques and learning strategies. Courses have been held for those concerned with planning at college level, and for teachers of both "vocational" subjects and general studies. Some of these courses have led, by design, to subsequent co-operative activity by course members and others and some of the results of this are included here.

Many of the themes of these courses have been well documented and there is not point in repeating the substance of lectures on those themes here. Those who wish to read books on curriculum design have plenty of choice. Those who wish to acquire techniques of objective writing or objective testing (two very different uses of the word objective) will find useful books which will enable them to apply the techniques to their own specialisms. What they may have difficulty in finding is help in deciding what to do in the teaching situation which will make a significant difference to the quality of technician education, without which all the organisational changes and preparatory programme and unit design would be pointless. Those who have attended the WJEC courses have been hopeful that significant improvements can be made in technician education but many have been outspoken in their fears that, at the level of impact on students, little may be gained.

The three sections of Part 1 rehearse the arguments of various lectures without the supporting visual and printed material which accompanied them. These

three sections focus on Objectives, Assessments and on Activity-based Learning Situations in turn, with the last of these as the main target of attention in which an attempt is made to reconcile the problems of preparing worthwhile objectives relating to transferable mental skills and personal qualities with the need to make valid assessments. In Part 2 a number of examples are given of activity-based teaching-learning situations which are intended to help interpret the principles discussed into practical and usable forms. These examples are based on ideas and experiences of teachers who have corresponded with me since the WJEC courses and who have discussed with me the responses of their students. They and others have suggested that the substance of the WJEC courses should be brought together in this way. I am grateful for their support and response.

Thanks are also due to visiting lecturers who have contributed to these courses and to leas and colleges who have supported the staff members who attended. In some colleges subsequent invitations to initiate or contribute to local activities have been appreciated and have led to the constructive development of my ideas.

I also thank those outside Wales who have asked me to speak on these themes and who have in return helped me by their discussion and argument. Some of my former colleagues at Garnett College and in Coventry will recognise their own ideas which I have absorbed gratefully.

These notes are a personal summary of the themes and outcomes of the WJEC courses mentioned. They must not be taken as having the approval of the WJEC, or of TEC, or of the DES.

John K. Millington, HMI
Welsh Education Office
Summer 1976.

PART I

SECTION I

MAINLY ABOUT OBJECTIVES

The present re-organisation of technician education has a number of features which have the characteristics of reform and even revolution. Such characteristics have given rise both to hopes that the new order will provide the opportunities for more effective teaching and learning and to fears that much of what has been valued in the old order will be lost. Total enthusiasm for new approaches as a means of escape from the present less than perfect situation seem to many teachers to be as dangerous and short-sighted as a total rejection of the need to change what has been done for years.

It can reasonably be claimed that, in the field of technician education, what has been most successfully done in colleges is the imparting of knowledge in traditional lesson situations. The knowledge imparted has consisted of factual information, scientific and technical principles and concepts and the application of these to fairly limited and stereotyped 'problems'. The knowledge has been identified in a syllabus and the 'problems' have been exemplified by examination questions. 'Problems', although widely used, are not really appropriate in this context because new problem situations are usually carefully avoided. 'Exercises' better describes the knowledge-testing but not problem-solving devices in common use. Whether the syllabus was a wholly given one by a body such as the City and Guilds of London Institute or one devised in colleges closely following guide-lines set by Joint Committees for National Certificates, and whether the examinations were wholly external or not, has not materially affected this emphasis on the imparting of knowledge in technician courses.

Because of this emphasis the teacher-centred and subject-centred lesson has predominated and when well used, taking advantage of the opportunities it provides for variety of activity (demonstration, discussion, questioning in both directions and student activity as well as direct exposition by the teacher), it has been very effective in achieving its purpose. Within the intrinsically formal teaching-learning situation inherent in the traditional lesson many teachers have found, or created, opportunities to involve their students imaginatively and to develop lasting relationships and attitudes which have made as great a contribution to their students' education as the more overt contribution signified by the acquisition of the desired certificate. The fact that many other teachers have not found, or created, these opportunities and have restricted themselves to lecturing to their students is regrettable both for their students and for their own professional job-satisfaction, but it is perhaps a consequence of the emphasis on the acquisition of examinable knowledge which has dominated technical education.

This domination is in danger of being replaced by another domination and although the 'best' teachers will resist pressures to de-personalize their teaching many of them fear that the new emphasis on specified objectives will encourage an impersonal approach to teaching which would sacrifice the best of further education's teaching traditions without providing corresponding gains. This fear may well prove to be justified but it is the contention here that it need not be so.

In the past our courses and the teaching-learning approaches have been dominated by the examination system. We have designed courses and have often stated course aims which have included more than examinable knowledge. The transferable mental skills of problem-solving, decision-making etc. the practical skills of technicians, and the personal qualities needed at work and away from it have often been given mention in the course aims. But most of these aims have been overlooked because they were not reflected in the assessment system. It is of course perfectly reasonable to devise a course and to intend to examine the students in the light of the course aims: but invariably we find that examinations can only assess limited achievements; so instead of examining what we wanted students to learn we move towards teaching what can be examined, which is very different. Teaching which is successful in helping students to acquire the ability to pass examinations is, not unreasonably, valued most highly and that which is intended to help students acquire those skills and qualities which are not easily examinable is regarded as a dispensible luxury.

So we have been dominated by the demands of examinations which led to the familiar concentration by teachers on examinable knowledge. It is no doubt for this among other reasons that the Technician Education Council wishes to see less emphasis on formal examination (Policy Statement June 1974). That desire is consistent with its strongly expressed emphasis that all programmes should aim to develop a range of transferable mental skills and personal qualities which it details in Circular 3/75. For this many teachers are grateful and see opportunities for genuinely educational advances in the TEC era.

But they fear that other domination which was mentioned before; the domination of objectives. They realise that externally set objectives may well have precisely the same limitations and inhibitions as those associated with externally set examinations. Even when objectives are formulated internally they fear that the externally set objectives will provide the models to be followed just as external examinations have done for college examinations. It is ironic that the many people concerned with the identification of objectives for TEC standard units who have spent a great deal of time, both in acquiring objective writing techniques and in preparing units in this way, have produced modern looking units which in fact specify objectives in precisely the limited 'knowledge' area that has been well enough specified in the past by the combination of vague syllabuses backed up by the case 'lore' of examination papers. Instead of being dominated by what can be examined, teachers who are concerned about the quality of technical education now feel threatened by the domination of what can be specified in externally set objectives. In both cases, what can be easily examined and what can be easily expressed in learning objectives, is precisely that same body of limited knowledge and its stereotyped applications.

This concern about the effects of specifying objectives is not a concern about the adoption by TEC of modern techniques of curriculum development. It is unquestionably better to specify what students are required to know or do in such a way that their achievement at a pre-determined standard can be observed, rather than specifying a syllabus as vaguely as we have traditionally done and relying on a few years of experience to clarify its meaning. But if inability to specify objectives which reflect the overall aims of TEC programmes has the same effect as inability to devise examinations to assess the achievement of the aims in previous courses had, then nothing will have been gained. Indeed there are real fears that since

objective writing skills are at present so limited there may be a trend to even greater trivialisation of content and to more mechanistic teaching methods. Nearly all the objectives appearing in TEC standard units could be achieved as a result of rote learning, mechanical note taking or repetition of standard solutions. It is often in fact claimed with approval that the means used to achieve an objective are unimportant. Caring teachers react instinctively against such an attitude which opens the door to near brainwashing techniques. The elevation of objective stating as the key issue in curriculum development is the most dangerous oversimplification which may produce the backlash which many fear. Examination of standard units issued by TEC so far leads one to the inevitable conclusion that it would be possible for a student to complete a programme of standard units (assuming that any college-devised units were comparable) without acquiring any of the transferable mental skills and personal qualities which TEC policy insists are to be developed in every programme.

Objective writing needs to be recognised as a tool in the curriculum development process which interacts with others and not as the necessary and sufficient starting point. Worthwhile objectives cannot easily, if at all, be written without concurrent consideration of the teaching-learning strategies and situations which are possible, without consideration of the resources and facilities available and of the possibility of valid assessments. This has been the difficulty of those preparang standard units but they have nevertheless worked hard and effectively to write objectives for the limited knowledge area in which there is considerable established expertise. The work done in preparation of standard units is not to be denigrated. The value to most colleges in having a series of 'packages' of identified 'knowledge' is the same as that of the agreed syllabuses we are familiar with. The additional value of having the time consuming work of writing objectives covering the basic information principles and routine applications already done for them will be gratefully acknowledged by many. Nevertheless the limitations of standard units are widely recognised. Those who care will use them as the basis of college units which also give due weight to the overall aims of TEC programmes and therefore to objectives of other kinds of which more will be said later.

It was claimed that to elevate objective stating to the key position in the curriculum development process was an oversimplification which was causing misunderstanding and an imbalance in standard units. There is no agreed consensus model representing the process to which one can refer for authority. However certain elements appear in all models and, however they are related in an interactive network, need to be given due consideration. One of these elements in Job-Analysis or Job-Study and TEC gave this some early and continuing emphasis. It was TEC's study of various investigations into what technicians do which led it to list the skills and abilities which technicians need, and it is its recognition of the need to continue to keep the output in mind which has led to its insistence on industrial consultation during the design of all programmes. It is notable that TEC identified the tranferable mental skills and personal qualities as most clearly emerging from the evidence it had. It is notable that objectives relating to these are hard to find in the available standard units.

PART 1

SECTION 2

ASSESSMENT ISSUES

Assessment is of great concern to teachers as well as students and tends to become more important and influential than the elements in the curriculum process which it is intended to serve rather than dominate. The way in which examinations have dominated teaching methods and distorted course aims has been referred to earlier. No doubt the assessment of TEC units and programmes will have a similar effect on what happens but the extent to which the aims are distorted will be in the hands of colleges as much as of TEC. TEC policy is to open the way to more varied and more valid assessments. Its policy statements that 'assessment must be related to the aims of programmes and the learning objectives of individual units' and that 'assessment techniques must be those most appropriate to the particular programme or unit' are direct and unequivocal and leave no scope for subsequent complaints that imbalance in a programmes' objectives or that overformal teaching methods are enforced by overformal examinations or inflexible assessment arrangements. Colleges should value this enlightened policy and take advantage of it to ensure that standards of technician education are raised as a result of assessments being more valid, in the sense that they assess the achievement of all the course aims not merely those which are easily assessable by examinations. The danger, which many fear, that objectives relating to the more easily identified subject knowledge area will dominate in exactly the way that examinations have done has been mentioned earlier, but it is a danger which colleges have it in their power to avoid.

Perhaps it could be claimed that in an ideal educational system there would be no place or no need for assessment, that assessment must inevitably distort the educational process which would be better off without it. This is not an uncommon attitude and some teachers do not make systematic recorded assessments unless imposed regulations oblige them to do so. Nevertheless there are few, if any, teachers who would deny their students the benefit of their experience by refusing to evaluate and comment on their students' work. Feedback to students of that sort must be based on an assessment taking into account the aims of the course, the point of the particular piece of work and the benefit which the students, individually and generally, might gain. The purpose of such assessments might be claimed to be very different from that required by regulations, Its purpose is to help in the learning process whereas that of regulation prompted assessment is to provide for certification, reports and records.

These two purposes of assessment

1. for certification or grading

and 2. for teaching-learning

are indeed seen as separate and conflicting by many and in practice they

have usually been so. There has long been a tradition that assessments for the first purpose are serious and should be made as objective as possible whereas those for the second are instinctive and subjective and once made have served their purpose. This traditional emphasis in engineering further education has led to the tyranny, which has been discussed before, that after planning to assess, usually by examination, what we intend should be learned, we move to teaching only those things which can be more or less objectively assessed, and end up valuing only those abilities which can be formally assessed.

If we reverse the emphasis and give priority to assessment for teaching and learning purposes other possibilities arise which do not have the effect of bringing the two purposes into conflict. In fact it can be fairly claimed that if assessments are made for teaching-learning purposes and if those purposes are in accord with the aims of the programme of study as a whole and are reflected in the teaching-learning situations devised, then the assessments will provide more valid information for certification, grading and reporting purposes than can be otherwise achieved. This is the rationale of continuous or course-based assessment rather than end testing and probably one of the reasons why TEC has advocated less emphasis on formal examinations.

Formal examinations should not however be dismissed out-of-hand. We cannot have been completely wrong all these years. The arguments for and against formal examinations as the main criteria of achievement have been heard in every staff room. For every argument on one side there is an opposing argument on the other. Sometimes the argument is the some on both sides but the tone of voice reverses its import. This list summarises many such arguments but is not comprehensive; nor, for bravity's sake, is the syntax consistent.

Formal Examinations

For		Against
Maintenance of standards	- but -	Well established unreliablity
Provision of goals		Wrong or undesirable goals
Guidance for teachers		Restricting for teachers
Impersonal		Impersonal
Objective		Subjective
Speed Counts		Speed Counts
Fair		Luck too important
Examiners are experts		Examiners are fallible
Involve stress conditions		Stresses are over influential
Final performance assessed		Once-for-all trial
Bring together several abilities (reading-comprehending-remembering-organising-communicating)		Reward verbal (reading-writing) skills more than others
Save teachers' time		Waste of teachers' professional skills and knowledge

These and no doubt other arguments will go on with some reason on both sides. However it is probable that few would claim that examinations provide the ideal and sufficient answer to the problems of assessment even if they think that with all their faults they are the best we have. It is unlikelythat we shall suddenly find an alternative which does all that we require, being valid for the whole range of programme aims and being sufficiently reliable to give complete confidence in the uses to which we put the results. The real case for moving away from, but not necessarily abandoning, formal examinations is that by doing more valid assessments can be made simply on the grounds that if there is a range of programme aims which can be interpreted by a spectrum of objectives in a variety of classifications, and that a variety of teaching-learning strategies and situations will be needed to achieve those objectives, then it seems inevitable that a variety of assessment techniques will be needed 'appropriate to the objectives and learning methods',

The following is a method, more simple than it may appear in cold print, that has been evolved in these WJEC courses for ensuring that assessments are more valid by design than those which are made for the sake of regulations. The method provides a necessary initial framework which recognises the aims of a programme to which a particular unit should contribute and the balance of objectives which need to be identified to achieve these aims; it recognises that some learning situations are more appropriate for achieving some sorts of objectives than others and that different assessments methods are applicable to these. (The greatest weakness of most of the published standard units arises from an apparent neglect, even reversal, of this procedure in that objectives were written and then classified in a particular hierarchy and summated. The summation then gave the balance of objectives instead of a pre-planned valid balance of objectives dictating the nature of the objectives to be written. The standard units, cannot therefore be combined, unimproved, to give a programme which achieves TEC aims but they are nevertheless of a great value in the following which gives them full credit for what they do).

Stage 1. Programme co-ordinators should look at programmes as a whole and decide what contribution each unit can make to the achievement of the programme aims which themselves need to be stated. For example a certificate level programme might be co-ordinated as follows:

Programme Aims		Balance of Objectives in Units				
		Unit 1	Unit 2	Unit 3	Unit 4	etc.
Vocational Subject Knowledge 60%	Information Knowledge Comprehension Routine Application	50%	80%	65%	60%	
Transferable Mental Skills 20%	Analysis Synthesis Evaluation Problem Solving etc.	25%	20%	15%	20%	
Physical Skills 10%	As specified	0	0	10%	15%	
Personal Qualities 10%	Response Organisation Leadership Co-operation Persistence etc.	25%	0	10%	5%	

The classification of aims and of objectives is not intended to be prescriptive. Any preferred classification can be used. The important thing is to identify, classify and 'weight' programme aims and to decide how units in different 'subject' areas can be planned to contribute to the achievement of the aims by adopting a particular balance of objectives. Clearly the contribution made by a Mathematics unit, a Science unit, a Workshop unit, and a Communication unit will each have a different balance of objectives which should be emphasised and not diminished.

Stage 2 Those responsible for the design and implementation of individual units can now carry out their work in a way consistent with TEC policy and the programme aims. They will of course have co-operated in the programmes analysis and be working with an agreed balance of objectives. If they have decided to use standard units then a great deal of work will have been saved in identifying the subject matter which will form the context of the unit. Time will also be saved later in specifying many of the objectives. Before specifying objectives however it is necessary to relate the balance of objectives given to possible learning situations and relevant assessment methods so that the statement of objectives does not get out of balance and dominate things to the extent of distorting the programme aims. The tail must not wag the dog. The following has been found to give a succinct one page summary of this which can be made by any teacher in his specialist subjects in an hour or so and provide a framework within which his objectives, learning strategies and assessments can be kept valid.

First,in the light of the balance of objectives given, the nature of the subject matter, the stage of development of the students and the local resources decide what are the most useful learning situations. The choice is wide but the selection will usually be readily made. Even lectures may play a part if team teaching techniques are to be used, although traditional varied lessons, laboratory work practical work, discussions, projects, role-playing, assignments, case-studies, tutorials and others will be, to different degrees, more relevant in technician education.

What is important at this stage, and what cannot be disregarded, is that each of these learning situations has its own characteristics and is particularly suitable for achieving different sorts of objectives. This will be dealt with more fully in Section 3 but it must be recognised now that projects, assignments, and investigations for example are not just names for vaguely the same thing distinguished only by such irrelevances as length of time taken, or number of students involved or degree of supervision. These are sometimes consequences of the differences in the activities, not determinants of them. It must be recognised now that although all the learning strategies adapted will use use the subject content of the unit as their context they will not all be solely or mainly used to impart or support the 'theory'. Laboratory work for example is generally inefficient in supporting theory, which lessons can do much better, but is, if well designed, most useful for other objectives. This theme is developed in Section 3 of Part 1 and in Part 2, but its import is implied here.

The selection of suitable learning situations having been made the job they have to do in achieving the balance of objectives can be allocated; in this method ticks are used in the appropriate columns of the proforma which follows. Looking down the learning situations column allows one to make a realistic approximation of the amount of time to be spent on each. Laboratory work may then be seen to justify, say, 30% of the time not for arbitary reasons but for valid ones. The over-reliance on one teaching method by a teacher will be avoided because no single method can meet all the demands made.

The assessment methods can now be related to both the balance of objectives, reflecting the programme aims, and the learning methods used, as TEC requires. The possible assessment methods available for selection are many and the following is only a guide for illustrative purposes:

Objectives Relating to	Opportunities for Assessment	Timing
Information Comprehension Routine Application	Traditional Examinations Objective Tests Oral Tests	During and/or at end of unit
Transferable Mental Skills	Traditional Examination (partly) Problem solving situations	During and/or at end of unit
	Investigation, Discovery and other 'laboratory' activities Projects Assignment etc.	During the activities
Physical Skills	Exercises	End and/or in-course
Personal Qualities	Laboratory and other participatory activities e.g. Projects, Assignments, Games, Case-work	During the activities

The choice and balance of assessment methods and their timing will be easy to decide from the complete unit plan, an example of which follows:

EXAMPLE OF UNIT PLAN

Programme: Engineering Technician

Unit Title: Level II 60 hours

Categories of Objectives according to Programme Plan / Selected Learning Situations		Lessons	Private Study	Laboratory	Assignments	Assessment Methods	% of Total
1. Basic Subject Knowledge	60%				✓	End Examination	20%
Information		✓				In-course objective tests	20%
Comprehension		✓					
Application		✓		✓			
2. Transferable Mental Skills	10%					Laboratory Work	15%
Analysis		✓		✓		End Examination	20%
Synthesis		✓		✓			
Evaluation		✓		✓			
Problem Solving				✓			
3. Skills	15%					Laboratory Work	10%
Laboratory Skills				✓			
Communication (technical)				✓	✓		
4. Personal Qualities	15%			✓		Laboratory Work	5%
Adaptability			✓		✓	Assignments	10%
Independence				✓			
Co-operation				✓			
Organisation			✓		✓		
Persistence			✓				
Reliability					✓		
Proportion different learning situations		60%	5%	30%	5%	In-course tests	20%
						End Examination	40%
						Laboratory Work	30%
						Assignments	10%

Note

The specification of objectives and the narrow selection of learning situations is merely illustrative. The range of situations and assessments is kept small to be manageable in the light of the constraints on most teachers in further education.

This simple unit plan enables many things to be seen in perspective and to be given their proper place.

1. The standard units (if being used) will be found very useful in the first group of objectives, the things we have traditionally done well in further education and must continue to do well.

2. The need to extend the range of objectives is not given merely lip-service.

3. The integration of some objectives associated with General and Communication Studies can be planned.

4. The role of laboratory work etc. is related to particular sorts of objectives and much former laboratory work is seen to be inappropriate.

5. The temptation of a teacher to concentrate on too limited a range of objectives or to use unvaried learning situations will have to be resisted because all valid approaches have been specified.

6. The balance of assessments based on course-work and on testing and the weighting given to the end-examination are established with respect to valid criteria and not by arbitary decision

7. The assessments are immediately useful in providing a 'profile' for reporting purposes which is more valuable than a summated mark. The objective tests may relate to basic knowledge, the examinations to more complex applications, the assignments to self-learning skills, laboratory work to transferable mental skills and personal qualities as well as to physical skills, and projects to realistic problem solving abilities.
(See part 1 Section 3 and Part 2).

8. The plan is not inflexible; being a product of professional judgement in the first place it is open to professional adjustment in the light of circumstances which arise.

A point which is inherent in much of what precedes but which is worth emphasising is that in-course assessment is not, as some have been assuming in colleges, a matter of spreading what was formerly covered by the final examination over a number of short tests throughout the programme or unit. There would be some advantages in this alone but not nearly enough to justify such a fuss as is being made about in-course assessment. The point is that subject knowledge tests, such as our traditional examinations and objective tests,can assess only a limited, even though important, range of objectives. The role of in-course assessment is particularly to cover those objectives the achievement of which cannot otherwise be assessed.

Many of the objectives which cannot be assessed by examination or objective tests also cannot be assessed very objectively. This does not mean that such assessments are less important they are precisely as important as the objectives concerned and the aims those objectives are designed to achieve. The confusion between the use of the word objectives in these two very different senses is unfortunate and has led to many misunderstandings. It is not difficult to write objectives involving transferable mental skills and personal qualities and it is not difficult to devise learning activities to develop these skills and qualities (see Section 3), but it may be necessary and proper to make assessments largely on a subjective basis.

If subjective assessments are the most suitable for some objectives then we must not hesitate to use them. Certainly the lack of objectivity must not lead to the abandonment of objectives which are valid and essential to the achievement of programme aims. Teachers are not teaching machines or merely instructors. Their professional subjective judgements and assessments, if well considered and based on valid activities are likely to be at least as informative and valuable in the contribution they make to certification and reporting as the more apparently objective ones.

PART I

SECTION 3

THE PLACE OF ACTIVITY-BASED LEARNING

Any teaching method consciously, instinctively or unthinkingly adopted must involve implicit assumptions about how people learn. In fact teaching has no better definition than "helping students to learn". This definition recognises that without learning there is no teaching and that learning is something students do with some active effort of their own, and in which teachers can help but not compel. Some prefer the word 'facilitator' to teacher to express this sort of idea but although that is unlikely to become general it is depressing that so many who should be teachers refer to themselves as lecturers and their job as lecturing. Passive teaching techniques (passive on the students part that is; the teachers concerned often work actively and hard in organising and understanding their subject matter and learn a great deal more than they ever did as students) assume, contrary to all the evidence, that students learn passively. Usually of course they make sufficient effort to pass examinations which call for little learning but some recall and repetition. They may do the same in apparently achieveing objectives which require them to 'list' or 'state' or 'solve' a "problem" just like this. In each case, as is well known, the students' abilities to do the same things, into which so much of the teachers efforts have gone, in two years or two months time will have faded. What is retained will probably be found to be irrelevant or outdated. Nevertheless the content of such teaching is the foundation for other continued learning and if it is incorporated into active rather than passive learning situations students will perceive its relevance. The scope for self-iniated learning, for independence and creativity, for self-evaluation and for learning how to learn are all greater in active learning situations and it is these and the associated transferable mental skills and person qualities which are not forgotten or out of date after a short time. TEC policy rightly stresses these things and in implementing its programme teachers and students must not be led to passive achievement of mundane objectives as their main aim. In engineering particularly, active methods are essential and through them can be achieved the sort of objectives of which Whitehead might have approved when he said that "education is what is left when you have forgotten all you learned at school".

Engineering courses have traditionally had a place for 'laboratory' or 'practical' or 'project' or other course work. It has been reasonably held that engineering is not only a 'theoretical' knowledge based activity but also one involving a knowledge of doing. The purposes of these activities have been surprisingly little considered by many teachers who devote perhaps a third of their teaching time to them. This despite some well considered statements on laboratory work by various bodies such as the former ATTI and repeated exhortations to individual colleges by the assessors of national certificates. Many teachers consider laboratory work to be a waste of valuable time and certainly many students get little satisfaction and considerable frustration from it. The reasons for these attitudes soon emerge from discussions with teachers and students. Teachers generally give two main reasons for doing laboratory work. One is to 'back up' the theory or something like that; the other is to carry out the course regulations. Nevertheless they know that laboratory work is a most inefficient and time-wasting way of backing-up theory. They know that a student who spends an hour or so collecting load and effort figures and measuring a simple lifting

machine and then a tedious time writing a report could do, probably has done the same thing in half an hour in class as far as supporting the theory is concerned.

If there is a real advantage in doing this sort of laboratory activity it is not apparent to the participants and not reflected in the assessments made. The teachers' assessments are almost wholly based on the 'theoretical' work done and the presentation of the report.

Students do not know what to concentrate their efforts on and so seldom enjoy the activity. If they concentrate on good calculations and graphs they are criticised for poor diagrams and 'method'. Almost invariably they are criticised for poor 'conclusions', to which teachers pay much lip-service, mainly because there were no clear objectives worth having conclusions about. When asked, teachers can usually offer no more advice on the vaunted conclusions than to suggest that students try to explain why the results were wrong, or inaccurate or differ from the "book". A depressing business which is little relieved by the use of 'proforma' laboratory reports which save time but leave the aridity of the activity involved unaltered and the search for reasons for error is highlighted. Very rarely even in the stereotyped 'experiments' which predominate is the accuracy or inadequacy of the theory questioned and the opportunity taken to draw to students' attention the assumptions and approximations of much of the theory they learn. Many 'laws' are proved over and over again despite like 'Hooke's Law' not being laws and not being provable.

However most teachers recognise many other purposes of laboratory work and the list of these can, in discussion, rapidly build up. The following is one way of classifying these purposes often mentioned.

Relating to 'theory' on subject matter

- Verifying principles, laws, facts, values
- Establishing 'new' principles, laws, concepts, facts
- Applying existing knowledge or theory

Relating to laboratory skills

- Calibrating, testing, equipment
- Assembling, setting-up apparatus
- Selecting equipment, instruments
- Learning to use standard equipment
- Using specialised equipment
- Following instructions

Relating to transferable mental skills

- Solving problems involving practical work
- Devising critical tests
- Identifying significant observations
- Making decisions, judgements and acting on them
- Discriminating between relevant and other information or theories
- Diagnosing
- Relating knowledge, information, theory from various sources; synthesising
- Analysing information according to appropriate criteria
- Generalising from particular situations
- Evaluating achievements, results

Relating to personal qualities

- Cooperating with others
- Leading others
- Working independently
- Recognising strengths and limitations
- Overcoming unexpected difficulties
- Having concern for quality
- Recognising deficiencies and outstanding needs

Relating to communication skills

- Organising and writing a technical report
- Writing for different readers
- Presenting information verbally and graphically
- Describing procedures, equipment
- Explaining decisions, analyses
- Relating output to objectives

This list is not intended to be definitive but does illustrate the scope for achieving in laboratory work so many things appropriate to technicians which can less readily be achieved in lessons. What a tragedy it is that in the enormous amount of time spent in laboratory work so few of these things are achieved by design although some of course, happen incidentally. The reason is that too often laboratory work follows a stereotyped pattern which offers scope for so many of these purposes that none are effectively achieved. Teachers hope for too much; students don't know what is expected other than a stereotyped report and little is achieved.

Yet where else can 'laboratory' skills be acquired? Where else can many of the transferable mental skills be developed so effectively as in realistic practical problem situations presenting challenges to students appropriate to their stage of development? Where else can some of the personal qualities be given the opportunity to emerge as in activities which require them to be exercised?

These are the things that laboratory work should be designed specifically to do, not the things that can be done more effectively in class lessons by demonstration or by routine exercise work. Most significantly of all it is the development of transferable mental skills and personal qualities to which TEC policy gives proper emphasis, which laboratory work and activity-based learning situations in general can perhaps uniquely contribute.

The examples of laboratory activities which follow have been collected from teachers who have tried to interpret Joint Committee and other policy in the light of educational principles, and developments such as the Nuffield projects. They are designed to present motivating challenges at levels corresponding to the 3 levels of Technician Certificate and Diplomas. They are designed on the principles well established by Bruner and others that for effective learning the learner must be an active participant not a passive recipient; he must be involved in acquiring knowledge, in selecting and arranging information, in making and changing hypotheses and in real or simulated problems as vehicles for learning.

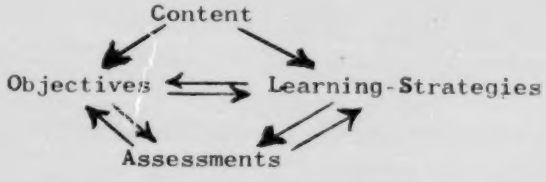
Active learning processes are particularly able to integrate topics both intra- and inter-unit in a way which is especially important to counteract the isolating-pigeon holing effect which the over-emphasis on behavioural objectives may create. For this reason it is difficult to imagine how TEC policy can be achieved unless the objectives of standard units are supplemented

by activity or task related objectives which can lead to generalized technician skills and abilities which the policy emphasises as so important. The standard units are deficient in this respect but are nevertheless of great value to those colleges which use them as the basic statements of subject knowledge to be acquired and devise new style activity based learning experiences in that subject area to give life to their units and programmes. As they stand the standard units appear to discourage this and make TEC policy difficult to achieve because they are so full with material that teachers may feel that they must 'teach' as quickly as possible by 'lecturing' to get through. They should remember that teaching is helping students to learn and without learning there is no teaching and that objectives relate to students' performance not to teachers'.

It is to TEC's great credit that it has recognised the central role which colleges themselves must play in programme design and that it does not impose standard units on colleges.

Colleges which adapt standard units, perhaps by reduction of their content, to incorporate activity - learning situations which have objectives in the field of transferable mental skills and personal qualities will be more likely to achieve the aims of TEC policy than those whose students merely achieve objectives of the kind found in the standard units. Once again it is stressed that this is not a condemnation of the standard units which provide a most useful basis in objective terms of the subject knowledge appropriate to particular technicians at particular stages. These subject knowledge objectives will rightly be the largest part of most units and provide the subject content around which the more educational objectives and activities can be devised. The standard units could not have been expected to cover more than the fairly mechanistic objectives they do because they were devised without consideration of the learning strategies and situations and resources which could be adopted by colleges. Once the whole teaching-learning situation is considered as an interacting whole then a more worthwhile range of objectives becomes possible since the strategies for achieving them and the ways of assessing their achivement can be planned with those objectives in mind. In fact it is difficult to find a published model of the curriculum process which even contemplates that a complete range of objectives for an educational course could be devised in isolation from the people and situations involved in the implementation of the course.

It is proper to expect that a body such as TEC should, after considering national needs, specify the general aims of its programmes. It is proper that specialist programme committees should identify the content appropriate to their programmes and to restate the general aims as necessary. Most writers on curriculum process expect the teachers to interpret the aims in the context of the content and to devise objectives, learning strategies and assessments in an interactive way. A typical modelling of this part of the process is



TEC has made what may prove to be a most valuable and pragmatic advance on the theorists in recognising that in most subject areas there is a basic body of knowledge which must be acquired by those studying the subject

and that the objectives relating to the facts and principles and their routine application can be assumed to be more or less the same for many colleges. That action by TEC will be most effective if the programme committees and colleges recognise that there are other important objectives which can only be written by those concerned with their implementation.

The activity-based learning activities given as examples later illustrate how objectives and assessments in the higher cognitive domain, that is the transferable mental skills, and the affective domain, or personal qualities, can be devised.

PART 2

INTRODUCTION

In this part realistic examples of activity-based learning situations are provided. The principles affecting learning and the ways in which learning can be facilitated to achieve more than a restricted range of objectives have been discussed in Part 1 and are not of course original. The claim for their validity is based on the fact that most respected writers seem to accept that the body of evidence about the way people learn leads to certain common principles even though many different structures are derived from those principles as a result of individual interpretations of them. The publication "How Students Learn" by the Institute for Reasearch and Development in Post-compulsory Education at Lancaster University, edited by Noel Entwistle and Dai Hounsell, 1975, will be found to provide a collection of relevant readings, all but one of recent origin. Some are related to learning in situations not closely related to those of technicians in further education but much is relevant if appropriately interpreted.

Discussion of these principles in the particular context of the further education of technicians at a time of change is appropriate because much educational writing is naturally related to learning in more generalised circumstances. The selection therefore of what seems relevant and us ful must be a personal one and should be a pragmatic one. What has gone before has been written with a view to what can be achieved in real life situations in colleges with all the associated constraints, and, what can, with appropriate care, be avoided by those with real concern for quality in technician education.

Quality will be determined not by the organisational structures that are set up and not by the volume of validation paper work which colleges produce. It will be determined by the experiences which students undergo. The quality of those experiences will not be determined by the particular information that students acquire from them. The informational content is so obviously important that there is no question that sufficient efforts are being made to ensure that the 'subject content' of units is relevant and adequate. What will determine the quality of the learning experiences is the nature of the challenges presented to students and the nature and variety of responses they make. The challenges need to be one which give opportunity for the development of students' abilities to think, and to apply their thinking consciously to real or simulated problems so that the mental processes are recognised, perhaps by verbalisation, and become transferable to subsequent problems involving other circumstances and increasing complexity. The challenges must provide scope for the exercise and development of critical powers, adaptibility, initiative and decision making. They must reward cumosity and originality and not aim at stereotyped solutions. They must involve personal interactive responses giving experiences in working with other people, sometimes as a leader, sometimes with people outside the normal class grouping.

These challenges can most readily be provided in activity-based learning situations. They will not however occur inevitably in such situations. Laboratory work is not necessarily a useful activity; it will not inevitably ensure that laboratory skills are developed; it will not help students to learn problems solving unless problems are presented. Project work will not achieve the aims which it is often assumed to achieve unless it is carefully planned to do so; much so-called project work is in fact very time consuming exercise work often with little thinking and a lot of routine activity.

The old maxim 'learning by doing' is a dangerous one; it needs to be interpreted not unthinkingly adopted. If the doing is without relevence, or does not involve the abilities and qualities intended to be developed then the students can be doing, perhaps quite happily and busily without learning what is interesting. Just as one can 'do' cookery by following recipes quite successfully without learning anything relating to creative or imaginative cookery, so one can follow recipe style laboratory exercises without learning anything to justify the truth involved.

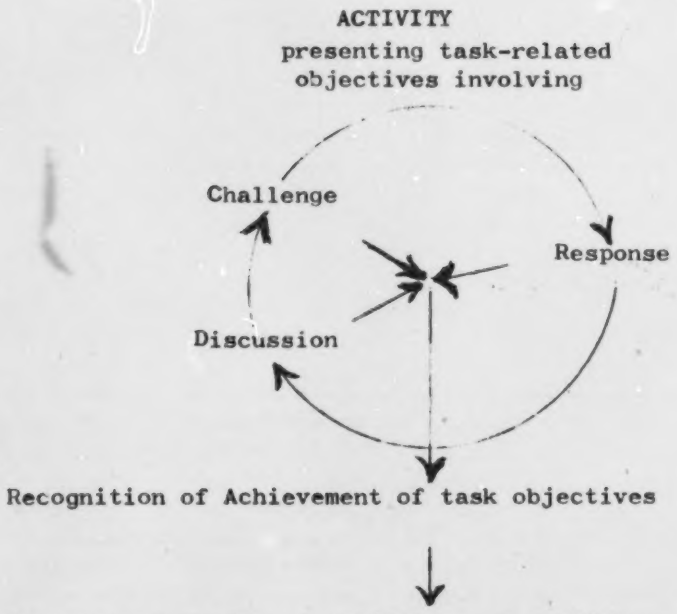
A useful model of activity-based learning processes is illustrated below. It recognises that objectives of the worthwhile kind which have been discussed can best be written with a particular situation in mind and not in initial isolation. The native of the activity devised in that context can then reflect (and modify constructively) the objectives. The model illustrates that the activity involves challenges, responses by students, and inter-actions with the teacher (called discussion) which contribute in varying ways (according to the nature of the activity and the responses of particular students) to an awareness that useful objectives have been achieved. The subsequent transfer of the abilities developed to later activities and to real-life is hoped for outcome rather than something which can be directly observed. It is however surely much more likely to happen if objectives relate to those abilities and the activities are designed accordingly, then if these abilities are merely given mention in the programme aims and subsequently assumed to be acquired by some mustic unplanned process. This transfer is also the purpose of education implied or directly stated by most of those involved, and if it were not so there would be little need for teachers to have professional abilities associated with teaching rather than 'mere' instructing.

Objectives

(Involving abilities and qualities beyond given information)

Context

(A situation arising from or consistent with the 'informational' or subject of a unit programme)



The activities which follow exemplify the kinds of situations which can be designed to achieve objectives relating to transferable mental skills and personal qualities and to other skills of a level which need practical situations in which to be exercised. They fall into 2 categories:

1. Laboratory Activities
and 2. Projects

Other activity-based learning situations, such as role-playing, games, and practical exercises are not included here because of their limited application to technician education in engineering. (Practical exercises have a valuable role in the achieving of objectives concerned with practical skills but these are well understood in colleges and need no special pleading). A brief section on assignments is appended to illustrate the particular role they can play although they are not interpreted as activity situations.

These activities are based on the actual experience of the writer, his former colleagues, and teachers (mostly but not exclusively in Wales). Not all have been checked in colleges in which they did not originate but many have been so used after modification to suit local circumstances. They should not be used without careful checking that the objectives are appropriate for the students involved and that the subject matter treatment is consistent with the teacher's own approach. In some cases it is necessary for students to have acquired the subject knowledge

involved; in others the activity is pointless if they have done so. Some of the activities may contain errors of fact or principle which have escaped editing although it is hoped that this is not do. In most cases, and contrary to traditional practice, little if any mention is made of apparatus or other equipment to be used; it is assumed that this will be available as required and if necessary separate operating or procedural instructions provided. The form of 'report' will also not be a stereotyped one and will have to be varied according to the activity. The main assumption throughout is that the teacher is a available to help, question, inspire and guide throughout and that the printed sheet should not leave all questions answered and difficulties overcome in advance.

PART 2

SECTION 1

LABORATORY ACTIVITIES PRESENTED AS TASK OBJECTIVES

This term is used to embrace a range of activities too diverse to be given a more specific name. The word laboratory may include places such as workshops or even classrooms when used for such activities. It is however a little more specific than simply 'learning activities' which is too indefinite to be useful in this context. The term includes investigations, problems solving situations, proofs and verifications of the conventional kinds and other activities to which it may be difficult to ascribe a specific name.

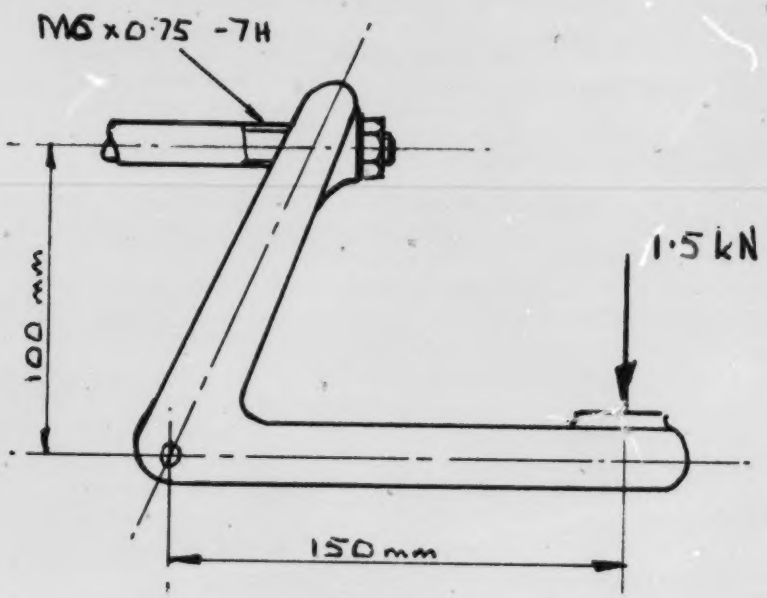
The objectives and scope of each activity is restricted by design. A fault of most conventional laboratory work was that too much was possible in each 'experiment'and that neither teachers nor students usually knew which of the many possible purposes were being served in each case. Many purposes were therefore ignored altogether in favour of routine stereotyped report-writing. In the activities which follow the objectives are limited to those which the teacher is assumed to have decided can best be achieved by each activity in the light of the whole programme of activities. The objectives are made clear to the students not by the pedantic statement of learning objectives in behavioural form, which would be calculated to dry up any student's motivation, by task objectives expressed in the form of simple direct statements of what he is required to do and the weighting which will be given to the various parts of the activity in the assessment so that he will be quite clear what to concentrate on.

This direct link between worthwhile objectives, identified by the teachers and the task related objectives given to students together with the associated assessment schedule is what distinguishes these activities from conventional 'experiments'. It is this link implemented in realistic activities which has been given the greatest welcome by many teachers who have taken the opportunity to break away from the tedium of much conventional laboratory work to achieve objectives which cannot easily be otherwise achieved.

LABORATORY ACTIVITY No. 1

TESTING AND SELECTION OF MATERIALS

The sketch shows a bell crank lever which is required to transmit force to a steel link. The link is to be made from material in stock to meet an immediate demand and it is necessary to select the most suitable of the four steels available. A safety factor of 4 based on the elastic limit is appropriate but the material must not be so brittle as to fail in service without substantial distortion. It should therefore be ductile to the extent of having a reduction of area at fracture in tension of about 30% or more and an elongation of about 20% or more (based on 16 mm gauge length).



Requirements and Assessment

1.	Tabulate the appropriate properties of the materials available using a Hounsfield Tensometer and associated instruments.	Design of Table Compilation of Values	5 20
2.	Select the most suitable material for the application. Give the reasons for your choice.	Reasons for Selection	20
3.	List the equipment used and show the calculations relating to the selected material.	List Calculations	5 10
			50

Arrange the report for the convenience of the Production Manager.

LABORATORY ACTIVITY No. 1 (Notes to teachers)

SELECTION OF MATERIAL

This is a simulated industrial problem situation with a sense of urgency built into it. It assumes that students already have the necessary theoretical knowledge and are either familiar with the equipment as a result of a classroom demonstration or have assistance in the laboratory by a technician or a set of instructions for example to enable them to use it completely. The theory and equipment are both used as 'tools' necessary to the solution of the problem and not as dominant features of the activity.

Learning Objectives

Application:	Students will apply their knowledge of moments and tensile behaviour of materials to a new practical situation as specified.
Analysis:	Students will analyse the given problem to identify what information is required. Students will analyse the information obtained according to specified criteria
Synthesis:	Students will relate all the information available and obtained in the content of the given problem.
Evaluation:	Students will evaluate their analyses and make and justify a decision based on the evaluation
Laboratory Skills:	Students will operate a Hounsfield Tensometer and associated equipment competently
Communication:	Students will draw up a technical report with limited objectives and with a particular reader in mind.
Personal Qualities:	Students will demonstrate their ability to work in a group, to adapt to difficulties arising and show concern for the reliability of their recommendations.

Notes: The problem is simply stated and immediately well understood by students. The forces and ductility criteria need to be set according to the materials available. If the teachers has say, six steels, he can set figures which are satisfied by only two. This gives him the choice of giving different students (according to ability and for variety) four samples of which one (easy), two (needing discrimination) or none (needing compromise) meet all the criteria.

Compare this with the usual comparison with published values! This elimination of routine descriptions etc enables this to be done in a normal $1\frac{1}{2}$-2 hour laboratory period. No unusual apparatus is needed.

LABORATORY ACTIVITY No. 2

RELIABILITY OF A MOTOR CAR BATTERY HYDROMETER

Cheap hydrometers are sold to enable the condition of the electrolyte in car batteries to be checked. This is an important indicator of the battery condition. The specific gravity of the electrolyte varies between the fully-charged and fully-discharged state. It is desired to check the reliability of typical cheap hydrometers for a consumer group.

Requirements and Assessment

1.	State the values of specific gravity for the electrolyte of a lead-acid battery when fully charged and fully-discharged.	Values	5
2.	Using a suitable quantity of water (for testing the hydrometer in an available vessel) and a suitable balance, add salt until the specific gravity corresponds to the discharged state of a battery. Test the hydrometers.	Preparation of fluids, care and accuracy.	15
3.	Repeat for the charged state.		
4.	Tabulate the results giving details of each hydrometer (including cost) and performance.	Clear informative table	10
5.	Write a report of 250 - 350 words for a local consumer magazine summarizing the tests and making appropriate recommendations.	Clear summary, Key points, Recommendations	20
			50

30

LABORATORY ACTIVITY No. 2 (Notes to Teachers)

RELIABILITY OF MOTOR CAR BATTERY HYDROMETERS

This is a situation with a good degree of inherent motivation for students and one to which a topic frequently included in General Studies units can be obviously related. The communication element gives scope for teaching a particular type of presentation. Basic theory is assumed to have been covered.

Learning Objectives:

Application: Students will relate their knowledge of specific gravity (or relative density) to a common situation and apply it to an investigation.

Students will apply their knowledge of consumer group activities and methods to a particular product.

Evaluation: Students will evaluate the results of their investigation according to relevant criteria from the point of view of non-technical purchasers.

Laboratory Skills: Students will prepare test liquids using precision methods and appropriate instruments.

Students will observe small differences in readings of instruments.

Communication: Students will present information in a tabular form.

Students will prepare a report for a general public focussing on key results and justifying the recommendations made.

Personal Qualities: Students will co-operate to produce an agreed report showing concern for accuracy and reliability.

Notes: This provides an obvious opportunity for co-operation between 'technical' and 'communication' teachers. The preparation of test liquids can be done in different ways using standard laboratory equipment according to the teacher's preference. Students will of course need instruction in this. The value of this activity is not restricted to motor vehicle students. Students who wish to include their own hydrometers should not be discouraged. Compare this with the usual experiment with 'specific gravity bottles' to obtain standard values (or not). Normal laboratory time and equipment only is needed.

LABORATORY ACTIVITY No. 3

Vibrating Timing Devices

Vibrations or oscillations of a pendulum have been the basis of many timing devices. The principles and theory involved in the oscillation of the simplest pendulum is fundamental to the study of more complex vibrations You are asked to prepare for this theory by investigating the characteristics of a simple pendulum.

Definition: A simple pendulum consists of a 'bob' of a definite mass suspended by a 'light' cord to a fixed point and free to oscillate without resistance in one plane.

A practical pendulum provided that its mass is concentrated near to the end of the cord is very close to a Theoretical pendulum.

Preliminary thinking When making a simple pendulum for investigation there are a number of features which may be varied. List as many of these as you can think of:

1. Mass of 'bob'
2.
3.
4.
5.
6.

Requirements and Assessment

1.	Make a scientific investigation into the effect which each of the variables listed has on the Period Time (τ) of a simple pendulum. (Keep all but one variable constant at a time and vary that one methodically and measure the period time for each value). Devise suitable ways to do this. Describe these in your report.	Variables Investigations	4 28
2.	Tabulate observations and draw graphs when necessary to establish each relationship.	Observations and graphs	10
3.	State each relationship in words and mathematically and evaluate any constants.	Relationships and constants	10
4.	Answer the following:		
	(a) What oscillation is now used in the international definition of the 'second'?		2
	(b) Pendulums used in the past for 'precision' timing were ingeniously designed so that changes in temperature did not affect their length. Illustrate the principle used.		3
		carried forward	57

5. The following is a 'thinking' experiment.

Consider a pendulum which 'beats seconds' (i.e. T = 2s). What would be the effect on its period,

(a)	if it was used on the moon;	2
(b)	if it was used in a lift moving;	
(i)	upwards and accelerating;	1
(ii)	upwards uniformly;	1
(iii)	upwards and decelerating;	1
(iv)	downwards and accelerating;	1
(v)	downwards uniformly;	1
(vi)	downwards and decelerating?	1
		65

LABORATORY ACTIVITY No. 3 (Notes to Teachers)

VIBRATING TIMING DEVICES - PRINCIPLE

This is a Theory related activity close to the traditional simple pendulum experiment but achieving worthwhile objectives instead of merely aiming to find a value of 'g' (as if students did not know it or as if this method would be used). It is important that students have NOT studied simple pendulum theory first. The assumptions of the theory (e.g. $\sin\delta \rightarrow \delta$) are routine on a chalkboard but the emergence of the same points in a practical situation is quite dramatic for students. (Surely the mass should make a difference, sir? Surely the angle matters more than this?). Students will identify possible variables readily (mass of bob, length of cord, angle of swing and often one or two others of interest) and, under guidance, acquire investigatory techniques; considerable imagination is often shown in setting up tests for each variable if no apparatus is provided other than standard bits and pieces and a clock. How to time a short period; How to reveal variations (1, 2, 4, 8, 16 rather than 1, 2, 3, 4 etc), are important techniques which can, with help, be discovered.

Learning Objectives:-

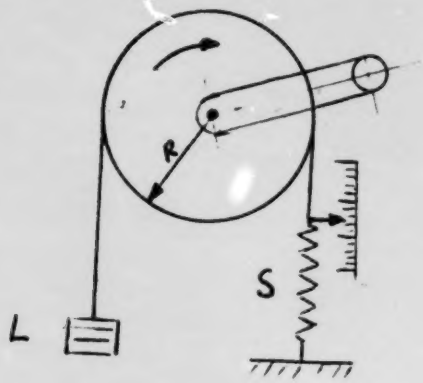
Information:	Students will acquire information on the behaviour of a simple pendulum which will be developed in subsequent theory.
Comprehension:	Students will select appropriate variables for investigation. Students will compare and forecast the behaviour of a simple pendulum under imagined situations.
Analysis:	Students will find the effect of each variable in turn on the periodic time and specify each effect in mathematical and general terms.
Laboratory Skills:	Students will isolate one variable at a time for investigation.
	Students will devise investigational techniques using general equipment.
	Students will select observational increments to give useful information.
Personal Qualities:	Students will develop initiative in devising experimental techniques and in overcoming difficulties.
	Students will recognise that assumptions need to be tested.

Notes: No theory should precede this activity.. After theory a different activity is needed. No equipment should be provided, let students select from what is around.

LABORATORY ACTIVITY NO. 4

MEASUREMENT OF PERSONAL POWER

In another activity you have (or will) measure the power available from your leg muscles. This activity concerns the power available from your arms. The apparatus is similar to that used for engine tests.



When the wheel is free and stationary L = S, but when the wheel is rotated the frictional resistance between the rope and the wheel reduces S. When turning the handle all the power is used in over-coming the frictional force (L-S) at radius R.

Power (watts)	=	Torque (Newton metres)	x	Angular Velocity (radians)

Requirements and Assessment

1.	Arrange a confortable load L (up to 150N) and handle radius by trial. Turn the handle steadily to overcome friction and record the reduced spring force.	Preparations	10
2.	Turn the wheel as fast as you can for 30 seconds. Count the number of turns. Calculate the frictional torque and average angular velocity and hence the average power developed.	Calculations	5
3.	Collect results for the group and compare the power produced with the weight of each individual (tabulate power; weight ratios)	Presentation	10
4.	Comment on the results for yourself (could you have done 'better' with a different load or handle length? What about your other arm? How long could you have kept it up? etc.). Comment on the group results.	Comments	25
5.	Discuss the energy changes involved.		5
			55

LABORATORY ACTIVITY NO. 4 (Notes to Teachers)

INDIVIDUAL DIFFERENCES - PERSONAL ARM POWER

Students are usually interested in their physical abilities and this activity (and a similar one relating to leg power) is a useful application of Theory in a motivating situation. Variations on it are used in many colleges. Here the non-routine treatment helps to maintain interest and allow for individual reactions. Some statistical examination of power-weight ratios can be developed, if desired.

Learning Objectives:-

Application:	Students will apply their knowledge of rational power to a new situation, and will discriminate between the concepts of ' 'instantaneous' and 'average' power.
Comprehension:	Students will go beyond the bare formulae $P=T\omega$ to explain how, in practice, the dimensions and other characteristics involved affect torque, velocity and the ability to sustain effort.
Communication:	Students will present their statistics and comment on both a group and individual basis.
Personal Qualities:	Students will be aware of individual differences Students will participate in a co-operative activity.

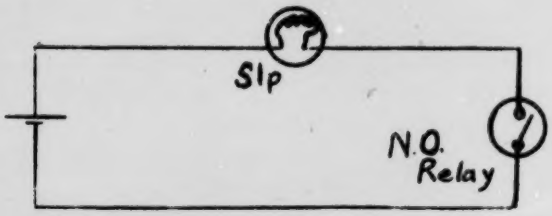
Notes:

A suitable apparatus may, exist or can after be easily arranged. No general laboratory skills are involved and there is no value in describing the apparatus or method used. The main purpose is to give theory more real meaning than the simple formula can and to motivate students to analyse their results imaginatively.

LABORATORY ACTIVITY NO. 5

AUTOMATIC WARNING DEVICE

The water in a tank must not be allowed to fall below a certain level and an indicator circuit has been designed as provided and shown below. It consists of a normally open relay (N.O. relay) which closes at low level conditions which switches on a signal lamp (Slp).



Check the operation of this circuit.
The circuit is unsatisfactory because it is not 'fail-safe'.
If there is a break in the circuit or if the lamp fails there will be no warning of dangerous water levels.

Requirements and Assessment

1. Modify the circuit design (without specifying values of components) so that, a) the lamp is at half brilliance in normal conditions; b) the lamp is at full brilliance at low level conditions; c) the lamp will be out if there is a circuit failure.	Circuit	15
2. Use appropriate instruments to find the values of the circuit components	Method and values	10
3. Calculate the value of new components needed	Calculations	10
4. Make up the modified circuit check its operation and measure the signal lamp voltage for each condition.	Operation to requirements	15
	Lamp voltage	5
		55

LABORATORY ACTIVITY NO. 5 (Notes to Teachers)

AUTOMATIC WARNING DEVICE

This is a design-related application of simple circuit knowledge. The principles of series and parallel connection of resistors are best established by controlled demonstration and there is little point in trying to 'prove' the relationships in the laboratory. This activity uses the concept of parallel connection in a situation which enables technician skills to be developed.

Learning Objectives:

Application: Students will apply simple circuit theory concepts and formulas to a practical problem.

Laboratory Skills: Students will select appropriate instruments to measure the appropriate properties of components.

Students will re-wire a simple circuit according to their own design and check its operation.

Notes: This is easily understood by students but achieves much more of a worthwhile nature than at first seems likely. The concept of fail-safe is important and is given meaning. The basic apparatus with a float in a 'tank' of water and a marked danger level can easily be made locally with a cell or battery and lamp on a board to which modifications can be quickly made. Instruments should be selected by students, rather than provided, so that thinking about ranges is necessary.

LABORATORY ACTIVITY NO. 6

EVALUATION OF YOUNG'S MODULUS BY BENDING

In a direct tensile test the value of E can be found by using the ratio $E = \frac{\sigma}{\epsilon}$ for loads within the proportional limit. This gives $E = \frac{F\ell}{Ax}$ or $F = \frac{EA}{\ell} x = \text{constant} \times x$

Thus a graph of F against x can be expected to give a straight line through the origin of slope $\frac{EA}{\ell}$ in which A and ℓ are easily measured so that E can be directly calculated.

The method to be used here is less easy in one respect, but in practice has great advantages. Think what these are during the activity.

In simple bending theory the expression $\frac{Mxx}{INA} = \frac{E}{Rxx}$ is established. Check the meaning of each term.

For a given beam of uniform section, which terms are constant for any loading?

.....

Which terms vary according to the loading? .....

Which of the constant terms is easily found? .....

Now if a beam is successively loaded so that the bending moment at a section XX varies and the radius of curvature at XX measured each time, then a graph of Mxx (vertically) against ..... should give a straight line of slope .....

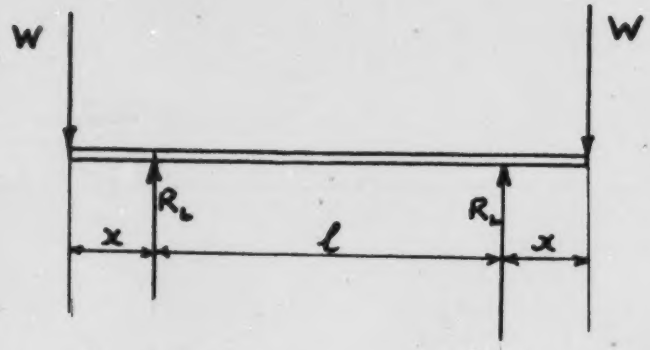
The difficulty in this procedure is the measurement of Rxx due to the fact that:

1. R is very large for bending within the elastic limit
2. If M varies along the beam (as is usual) then R is varying also along the beam.

So the whole point of this method is to overcome these two difficulties. It is necessary to find a loading method which gives a constant bending moment along the beam (or a good part of it) so that R is constant along that length (which means that the beam bends in an arc of a circle for that length).

A loading system which achieves this is as shown overleaf

continued.....



Loading Diagram

Sketch the bending moment diagram.

Over what length of the beam is the bending moment constant for a given loading W?

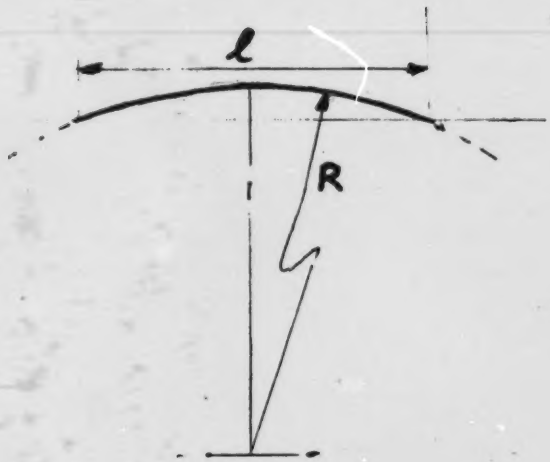
.....

.....

What is the value of that constant bending moment?

.....

.....



Deformation Diagram (exaggerated)

For the circular arc

$(2R - \delta)\,\delta = \frac{\ell^2}{4}$ because .....

.....

hence

$R = \frac{\ell^2}{8\delta}$ because .....

.....

Now a direct measurement of δ (which is easy) give R which was the difficulty.

Now it is easy to apply a series of loads W and measure δ each time. These allow M_{xx} and R_{xx} to be calculated and plotted as originally needed to give the value of E.

Requirements and Assessment

1.	Complete the introductory work above	10
2.	Tabulate W and δ and hence Mxx and Rxx (show the values of ℓ and x chosen above)	15
3.	Plot a suitable graph and evaluate E	15
4.	Comment on the advantages of this method over a tensile test.	10
5.	Make a labelled sketch of the set-up	5
		40
		55

LABORATORY ACTIVITY NO. 6 (Notes to Teachers)

EVALUATION OF YOUNG'S ELASTIC MODULUS BY BENDING

This activity has exactly the same objectives as the traditional experiment: However as teachers know, and as a few words with any students who have carried out the usual 'experiment' will confirm, the important concepts involved are completely missed because, all the students are asked to do, is to follow recipe-like instructions and plot a graph the slope of which with a bit of juggling gives E. All that students need to know is how to measure a slope (sometimes that is given) and how to transpose the value for E (also sometimes given). A potentially valuable activity has no value because even the apparatus is intended solely for this 'experiment' and using it leads to negligible transferable skills. In this revised activity the same things are done but the student is made to think about each stage. Students will be familiar with $\frac{Mxx}{I_{NA}} = \frac{E}{R_{xx}}$ (the suffixes are important for comprehension but often omitted) but the assumptions involved and the meaning of each term are often unimportant in the stereotyped examples students are given. This activity emphasises concepts and develops understanding very effectively.

Learning Objectives:

Comprehension: Students will select and classify constant and variable terms from the basic formula according to a given situation. Students will select key variables for plotting and indicate how the required constant will be extracted. Students will explain the advantages of finding E by bending.

Application: Students will use their knowledge of bending moments and properties of intersecting chords of a circle. Students will demonstrate their competence in using a graph to a desired constant from a set of observational values.

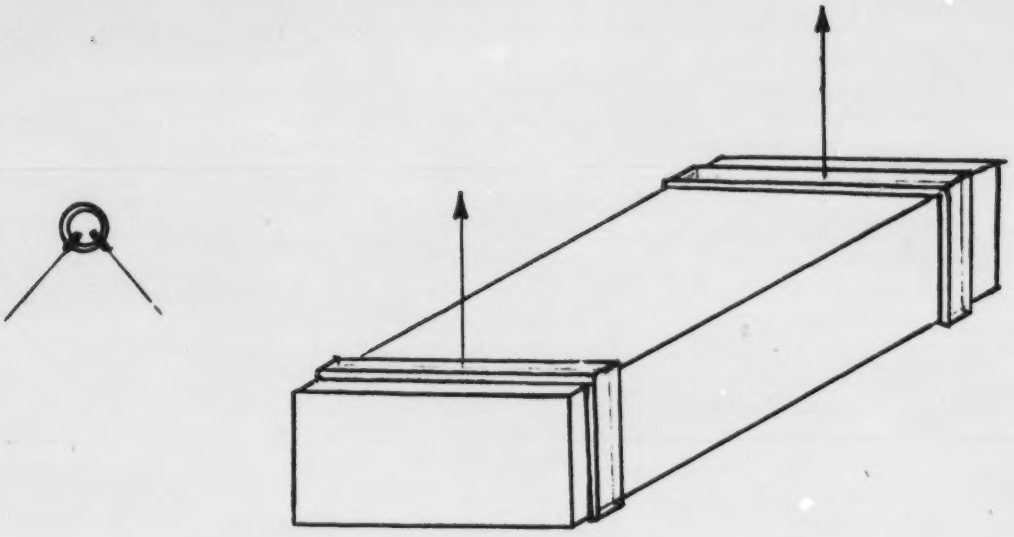
Evaluation: Students will recognise the value of a low force high-deflection method of material testing.

Note: Some may feel that too much help is given to students and that more could be demanded in respect of the loading used. Compared with the usual 'experiment' which asks nothing of significance of students there is probably sufficient here for most students.

LABORATORY ACTIVITY No. 7

DESIGN OF A SLING TO LIFT A PACKING CASE

The packing case provided is the prototype of a production run. It contains the equipment to be packed. It is necessary to design a simple two-legged sling so that the cases can be lifted without tilting. The sling is to be made of wire with a safe load rating of 500N. The two lifting points are shown.



Requirements and Assessment

1.	Use any appropriate equipment and method to find:	Weight - Method	10
		- Accuracy	3
	(a) the weight of the case;	CG - Method	10
	(b) the position on the top face below which the centre of gravity lies.	- Accuracy	2
	Describe the methods used.		
2.	Design a sling of the type illustrated to lift the case without tilting. Show your design process clearly and state the lengths of the two wires which will result in the safe load being carried. State whether these lengths could be increased or decreased safely.	Design Method and Dimensions	20
		Effect of Variation	5
			50

LABORATORY ACTIVITY No. 7 (Notes to Teachers)

DESIGN OF A SLING

This activity usefully replaces the dull 'experiments' to 'verify' the principle of moments' and 'the triangle of forces' both of which can be better done by controlled demonstration. Substantial forces are involved so that small errors due to sticking pulleys, weights of cords, etc. are not important. The purpose of the activity is clear and relates to real life. It will be found that a solution to the design problem cannot be obtained directly by a graphical or analytical method by students at the stage at which this activity would be used. This leads to the opportunity for the teacher to discuss the difficulty and to help students to a solution by successive trials of increasing lengths of sling from the minimum possible but keeping the given and discovered dimensional constraints in mind. The concepts involved in co-planar force systems are very effectively reinforced as a result in a way that is impossible in stereotyped exercises in class or laboratory.

Learning Objectives:

Application: Students will apply their knowledge of the principle of moments and the equilibrium of co-planar forces to a new practical problem.

Comprehension: Students will select valid methods to find the information required.

Students will explain the effects on safety of varying the lengths of a sling.

Notes: The given safe load must be related to the weight of the box or vice-versa. The box can be loaded so that the weight and CG position is different for each group of students. The equipment made available should not make it possible to find the weight and CG position directly. If desired students with the time can be required to test their design on the usual fares boards by suitable scaling down. Alternatively the design can be carried out by using a scale simulation on the force boards and trial methods. Such methods are valuable in helping to overcome attitudes that results based on theory and calculations are 'better' than those based on actual observations.

LABORATORY ACTIVITY No. 8

EFFECT OF WATER CONTENT ON STRENGTH OF CONCRETE

The properties of concrete depend on a number of factors. You are asked to find the effect of varying the amount of water used in the mix on the compressive strength. Other factors must not therefore be varied.

Requirements and Assessment

1.	Make six concrete cubes using the mix provided but varying the amount of water used from the least to the most that is practicable	Preparation of samples	15
2.	Test the cured cubes to destruction using the Denison Testing Machine. Tabulate the results.	Tests Table	5 5
3.	Calculate the strength of each cube and plot a graph relating this to the water content.	Calculation Graph	5 5
4.	Write a short article, about 500 words, for a Do-it-yourself magazine describing the results, explaining them by reference to appropriate chemical equations and indicating the practical implications	Presentation of information Explanations Implications	10 10 15
			70

LABORATORY ACTIVITY No. 8 (Notes to Teachers)

EFFECT OF WATER CONTENT ON THE STRENGTH OF CONCRETE

This differs little from a familiar 'experiment' but the point is emphasised and the opportunity taken to require a report of a non-stereotyped kind. The ways in which graphs need to be displayed and other information presented for a non-specialist magazine will clearly need to be considered in consultation with the communications teacher.

Learning Objectives

Information:	Students will obtain and state in an appropriate way the relationship involved.
Application:	Students will demonstrate their knowledge of principles of verbal and graphical presentation of written information for a specified readership.
Laboratory Skills:	Students will make samples using standard techniques. Students will use a standard testing machine competently.
Personal Qualities:	Students will organise their material with the needs of others in mind. Students will indicate the value of their results in general use.

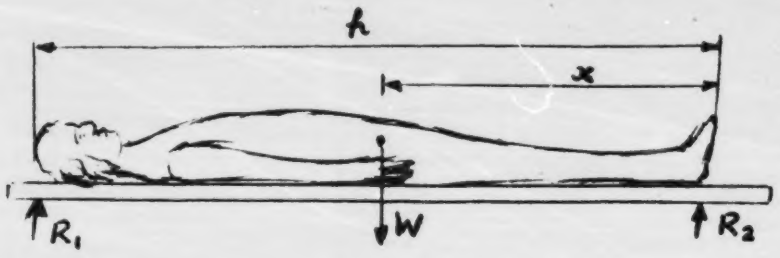
Notes: The extent to which other constituents in the mix are decided by students or the teacher will need consideration.
The use of the testing machine alone or with help will depend on previous activities or instruction.

LABORATORY ACTIVITY No. 9

POSITION OF CENTRE OF GRAVITY OF PEOPLE

People are remarkably similar in important functional respects but vary considerably in appearance and 'personality'. In this activity you are asked to find out how the positions of peoples' centres of gravity vary. Obviously the CG varies with height but is it always at the same proportion of height? Does it vary with build, sex, age? Find out as much as you can for the group of people available (your class, teacher, other classes willing to help).

The Principle of Moments is easily applied to give the results required.



Taking Moments about the feet $\sum M = 0 \circlearrowright +$

$R_1 H - Wx = 0$ of which only x cannot be directly measured.

$x =$ .....

Requirements and Assessment

1. Measure and record the weight and height of each individual in the survey. Also record the other details required by the table below. — see below

2. Support a plank by two compression balances separated by the height of an individual. Zero the balances. When the person concerned is lying on the plank record R_1. Check that $R_1 + R_2 = W$ before crecording R_1.

   Calculate x and the ratio x/h and complete the table

Practical work	15
Calculations	10
Table	10

3. Discuss the results. How constant is the ratio x/h? Is there any apparent correlation of x/h within particular groups e.g. the shorter, taller, plumper, thinner, male, female, younger, older? Examine the few highest and lowest values of x/h to see if there is any significance in them. Write about 300 words on your findings.

Clarity of Analysis	15
Presentation	10

Table Layout

Individual	Sex	Age	Build	Height (metres)	Weight (newtons)	R_1 (newtons)	x (metres)	x/h	Order of x/h

LABORATORY ACTIVITY No. 9 (Notes to Teachers)

INDIVIDUAL DIFFERENCES - POSITION OF CENTRE OF GRAVITY OF PEOPLE

Another activity using the intrinsicially motivating interest of people in people to apply a basic principle. The activity although not obviously related to technicians work is an example of an investigation into unknown areas of knowledge. Information on the $^{x}/_{h}$ ratio may exist in physiological reference books but it is unlikely to be readily available to teachers and students in this situation. It may be claimed that the information is not important for technicians to know but that is to miss the point (and if valid would eliminate a great deal of what is taught!). Students seldom analyse their subject matter for relevance if they find that it is made interesting. The most frequent criticism made by students of their experiences in education relate to being bored. It does not help (although often said) to say 'this topic will be found important later on'. Students ask for and deserve to be motivated by interest 'now'. This activity illustrates the point.

Learning Objectives

Application:	Students will apply knowledge of the principle of moments to a simply supported beam situation
Comprehension:	Students will acquire an understnnding of the complexity of statistical data by comparing the results obtained for x/h with other characteristics.
Laboratory Skills:	Students will show their ability to eliminate irrelevant effects (ie weight of plank), and to keep measurements consistent.
Analysis:	Students will compare their discovered data for x/h with other individual characteristics.
Synthesis:	Students will correlate their information with that of others and generalize from it.
Personal Qualities:	Students will participate in a co-operative investigation. Students will recognise individual differences and similarities.

Notes: Although some useful results can be obtained from a single group of students the opportunity to collect those of others at the time (teachers, technicians, students in other courses etc) and over a period should be taken. Compare this with finalising beam reactions by 'experiment' and calculation!

LABORATORY ACTIVITY No. 10

CORROSION DUE TO ELECTROLYTIC ACTION

Electrolytic action is one of the most serious causes of corrosion in metallic materials. Basically it occurs when two dissimilar metals are in contact with an electrolyte. The electrolyte may be trapped dampness on other liquid. The two 'metals' may differ only in heat treatment or even be merely slight differences in structure or impurities in an apparently homogeneous material. Some pairs of metallic materials corrode together more rapidly than others and their use in corrosive situations must either be avoided or the effects reduced unless the corrosive action is a desirable one.

Requirements and Assessment

1.	Take one pair of materials at a time from the range provided and measure the emf generated between them in a salt solution. Note the polarity as well as the magnitude of the emf. Tabulate the observations.	Use of Instruments Table of Values	5 10
2.	Examine the results carefully. Make a list in order of greatest 'positiveness' to greatest 'negativeness'.	List	10
3.	It is the anode of an electrolytic pair which is corroded. Use the list found in 2 to make comments on the following:		
	a. Which pair will give rise to the most rapid corrosion? Which material 'suffers'?		5
	b. The use of brass screws in aluminium castings		5
	c. Tin and zinc plating of mild steel		10
	d. Any two situations in your firm in which corrosion occurs		10
	e. The idea of a 'sacrificial anode'.		5
			60

LABORATORY ACTIVITY No. 10 (Notes to Teachers)

CORROSION DUE TO ELECTROLYTIC ACTION

This activity can be related to classroom work on primary cells requiring no more than elementary knowledge of cells but leading on to a most important consequence of the action involved. The principle of electrolytic corrosion is usefully introduced at an early stage even though it will not be treated more 'theoretically' until later. A great deal of useful thinking of a technician kind is made necessary for students.

Learning Objectives

Information:	Students will lable the relative anodic-cathodic relationships of pairs of materials and list an order of corrosion risk.
Comprehension:	Students will select from their list information which answers relevant questions.
Laboratory Skills:	Students will make measurements of small emfs selecting appropriate ranges on the instruments.
Personal Qualities:	Students will recognise the significance of the information obtained. Students will relate the knowledge gained to their employer's situation.

Notes: There are obvious opportunities for informal treatment of historic ideas of 'nobility' as well as more modern topics. There is some useful industrial literature on this subject which could be available to students for general interest. An increase in marks for comments on individual industrial situations might be justified if teachers ask for substantial information. Compare this with checking the emf of Leclanché and Daniel Cells!

LABORATORY ACTIVITY NO. 11

AIR-OPERATED PRESSURE SWITCHES IN AUTOMATIC WARNING DEVICES

The head of water in an open tank is to be monitored by using sealed pressure switches. Each switch consists of a beryllium-copper capsule which expands when the pressure of air inside it increases and the movement is transmitted by levers to a micro-switch. The pressure differential of each switch depends on its specification; some adjustment can be made. Two FCI pressure switches, a monometer and a three lamp test board are provided. One switch is 'high-pressure', the other 'low-pressure'. It is necessary to calibrate and set the switches to maintain the level of water between 500 mm and 600 mm above the position of the switches.

Requirements and Assessment

1. Use the laboratory air supply and monometer to check the operation, the pressure differential and the range of adjustment of each switch.	Method used Presentation of Observations	10 10
2. Set up a circuit so that the laboratory air supply can be used in conjunction with the monometer and the switches to operate the three lamps as follows:	Design and set up (to be checked before operation) Safety considerations	20 5
3. Check the operation of the set up and adjust to give the required operating heads.	Operational Adjustments	10
4. Comment on the degree of accuracy of the switches and the method of adjustment. Record and comment on the set ups used.	Comments	10

Pressure lamps	1	2	3
below 500 mm	on	off	off
at 500 mm-600mm	off	on	off
above 600 mm	off	off	on

65

51

LABORATORY ACTIVITY NO. 11 (Notes to Teachers)

AIR-OPERATED PRESSURE SWITCHES IN AUTOMATIC WARNING DEVICES

This is an activity designed to familiarise students with a standard item in such a way that technician level abilities involving calibration, adjustment and the use of other equipment and knowledge are developed. Values quoted will have to be altered to suit the equipment available and the amount of guidance needed will depend on the previous work done in class.

Learning Objectives

Application:	Students will construct pneumatic and electrical circuits which require previous knowledge of the principles involved.
Synthesis:	Students relate theory and knowledge of'hardware' in a new situation.
Evaluation:	Students will assess the accuracy and suitability of the switches in the devised situation.
Laboratory Skills:	Students will check the operation of the switches and calibrate their range. Students will set up and adjust their approved arrangement to meet specified criteria.
Personal Qualities:	Students will demonstrate concern for safety. Students will criticise their work in the light of experience.

Note: Similar activities could be devised for familiarising students with various devices. The motivating value of activities which are seen to be related to technicians' work rather than merely to book-work is considerable. Too many 'hardware' focussed activities are little more than repetitions of text books descriptions after a routine test involving little thinking and therefore having little lasting value.

LABORATORY ACTIVITY NO. 12

CUTTING PROPERTIES AND MICROSTRUCTURE

The college training centre has not been able to achieve as high a cutting speed with a satisfactory finish when cutting a particular steel. The trainees have tried varying the machining conditions but now suspect that the structure of the steel is not suitable. A report is requested.

Requirements and Assessment

1.	Contact Mr.....to obtain a sample of the steel and to examine the results of cutting tests made. Briefly describe these and the stock material.	Descriptions	10
2.	Prepare the specimen for micro-examination.	Method Finished Specimen	10 10
3.	Examine the specimen. Sketch the structure as observed. Compare it with photo-micrographs in ..... and refer to class notes. Discuss your observations and make a brief report for Mr. ..... giving such information as you have been been able to deduce and making recommendations about the use of the steel concerned.	Sketch Report Deductions Recommendations	5 15 15
			—
			65
			—

LABORATORY ACTIVITY NO. 12 (Notes to Teachers)

Cutting Properties and Micro-structure

Here is a routine technique brought to life by being given a real, or realistic, purpose. This is developed from a situation which actually occured which the teach concerned turned to advantange. The fact that such chances can (if recognised) be extremely valuable is clear but they do not happen often enough or when they do, so providentially. It is therefore necessary to set up situations so that students are stimulated in the way that they are in ones which occur in real life. The value of discussing a problem with another teacher and helping to solve his problem has obvious industrial parallels which are lost if a routine test is carried out to compare observations with those in a book and explain differences.

Learning Objectives

Analysis:	Students will compare elements in micro-structures and identify particular characteristics.
Evaluation:	Students will determine whether ovserved characteristics relate to the problem in hand
Laboratory Skills:	Students will demonstrate the technique of preparation of specimens for micro-examination and produce a satisfactory surface.
Personal Qualities:	Students will respond to the difficulties of others and associate themselves with the problem. Students will establish a co-operative relationship with those in another'department'. Students will recommend action taking into account the interest of others.

Note: This is an example of an activity in which staff and students act in mutually consultative roles. Instructions for the preparation of specimens can precede the activity or be provided at the time. The techniques involved should be made subservient to the problem rather than be thought to be the main purpose. This will be found to result in more care to produce good results because the problem needs them.

LABORATORY ACTIVITY NO. 13

BEYOND THE 'ELASTIC LIMIT'

The behaviour of various metals in a tensile test to destruction has been observed. Subsequently a study of the Theoretical consequences of the behaviour of materials, which deform proportionately to the load has been made (such materials are said to be Hookean. During the proportioned range most materials are largely elastic. Investigate the elasticity of two materials beyond the limit of elasticity.

Requirements and Assessment

1.	Define elasticity, proportional limit and yield point.	3 Definitions 10
2.	Use the Hounsfield Tensometer to stretch each material until proportionality of extension to load ends. Plot the graph from the beginning. Continue loading until the 'apparent' extension is double that at the proportional limit. Mark the graph and reduce the load to zero, marking the graph several times. Re-load without making any changes. Mark the graph but distinguish unloading and loading points. Repeat for further increments of extension.	Graphs Clearly presented and labelled 25
3.	Describe in words what happens when a material is stretched beyond its elastic limit and subsequently unloaded and re-loaded.	Key points 15
4.	A material was found to be fully elastic up to a stress of and to have an ultimate stress in tension of A sample was loaded in tension to a stress of and then unloaded. Guess how it would behave when subsequently loaded to destruction.	Description of 'guess' 10 Justification 10
5.	Suggest an application taking advantage of this phenomenon.	Application 5
		75

LABORATORY ACTIVITY NO. 13 (Notes to Teachers)

BEYOND THE ELASTIC LIMIT

This is a good example of a genuinely investigative activity because it takes students beyond their previous studies into a phenomenon they may not study until a subsequent year or unit. In doing so it reinforces most effectively the concepts they have acquired and may well give them meaning for the first time by emphasising the limited application of proprotionality theory. By themselves the new concepts involved are important in practice and provide a valuable platform for discussion for an informed teacher.

Learning Objectives:

Application:	Students will use existing knowledge of the behaviour of materials intension to find new information.
Analysis:	Students will examine the new information and identify the characteristic behaviour involved.
Communication:	Students will translate observed behaviour into a verbal description.
Synthesis:	Students will generalize from the materials studied to a postulated new situation.
Evaluation:	Students will justify their generalizations.
Creativity:	Students will suggest 'new' uses of the discovered phenonemon.

Note: The choice of two materials to be given to the students provide opportunities for the teacher to vary the investigation for different groups with obvious advantages. The use at 4 of a 'thinking experiment' is more positive in checking students understanding than to vague conventional 'conclusions'.

LABORATORY ACTIVITY NO. 14

ENERGY CHANGES IN A FLOWING LIQUID

A liquid flowing through a pipe of varying section will undergo changes of velocity and pressure. These changes are associated with changes in the forms of energy of the liquid. There are three major forms of energy involved in this situation and you are asked to prepare for a subsequent theoretical study of this important situation by finding out how, in practice, the energy changes are related. The energy forms involved are already familiar. They are:-

1. Kinetic Energy - $\frac{1}{2}mv^2$ (SI unit of each term)
2. Pressure Energy - $m\frac{p}{\rho}$ (SI units)
3. Potential Energy - mgZ (SI units)

For an 'incompressible' fluid in a full pipe the mass flow rate is clearly the same at all sections so the energy per unit mass of liquid is $\frac{v}{2}, \frac{p}{s}$, gZ respectively, the units of each of those terms being .....
Investigate the variation of each of these quantities for water flowing in the inclined pipe of varying section provided.

Requirements and Assessment

1.	Adjust the flow rate to give large differences of readings on the pressure gauges. On the drawing provided record these pressures converted if necessary to SI units as above. Measure the volume flow rate and calculate the velocity at one section and at other sections in proportion. Record these and the head at each section on the drawing using SI units throughout.	Completion of drawing with all relevant information	15
2.	Using the length of the pipe as the horizontal axis plot 3 independent graphs of $\frac{v^2}{2}$, $\frac{p}{\rho}$, gZ using the same units for each; consider the shape of each graph between the sections at which measurements were made carefully.	Three graphs	10
3.	Combine the 3 graphs in a single graph in which the quantities are added successively. Comment on the relative magnitudes of the 3 quantities summated.	Summated graph Comment	10 5
4.	Make a hypothesis about the energy of liquids flowing in a full pipe. State its basis and any reservations or limitations which may apply. Comment on the assumptions you made at Stage 2 about what happened between measurements.	Hypothesis Reservations Comments	15 5 5
			65

LABORATORY ACTIVITY NO. 14 (Notes to Teachers)

ENERGY CHANGES IN A FLOWING LIQUID

This is an example of a rather dull routine 'experiment' to 'confirm' or even 'prove' Bernovilli's theorem, which usually becomes a tedius search for 'errors', being converted into a discovery learning situation which can very effectively establish several basic concepts from which class teaching of theory can subsequently benefit in both time saving and effectiveness. It is important that students attention is focussed on the concepts involved and to do so as much incidental routine work as possible should be avoided. The diagram provided should give key areas of the pipe section in SI units not diametas. Pressure measurements should be made directly in the appropriate units if possible or a conversion chart provided. The volume flow rate should be directly measureable in SI units. The associated calculations from other measurements are better practised in classwork and homework exercises; here there are things to be learned that cannot be done eleswhere.

Learning Objectives

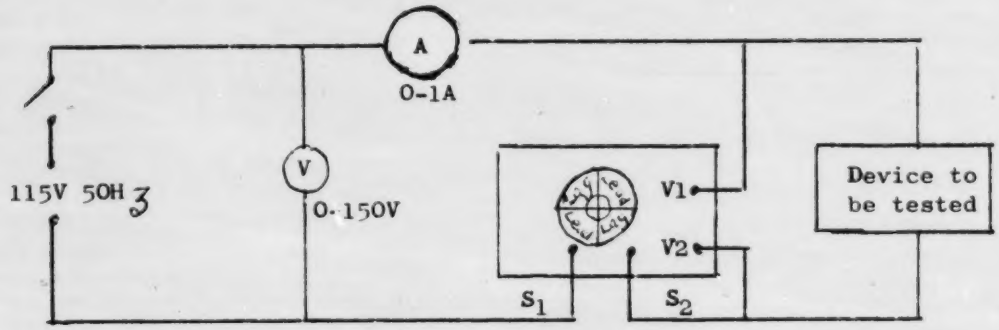
Application:	Students will use previous knowledge of the 3 forms of energy involved in a new situation.
Synthesis:	Students will combine previously separate energy studies to form a new concept of total energy of a fluid.
Analysis:	Students will conclude from direct evidence that in the given conditions $\sum\left[\frac{v^2}{2} + \frac{p}{\rho} + gZ\right]$ = Constant Students will justify their conclusion and identify possible limitations. Students will compare the relative magnitude of the 3 terms in the given situation
Laboratory Skills:	Students will use a variety of instruments and correlate the units of measurement as needed.
Communication:	Students will present information graphically, including the use of a summated graph.
Personal Qualities:	Students will recognise that they have participated in a process of discovery.

Note: The requirements opposite could well be shortened if factual information about the apparatus is readily provided in a convenient form. Students should be familiar with the 3 quantities involved separately which at this stage will mean that only the $\frac{P}{\rho}$ term need be dealt with in class.

LABORATORY ACTIVITY No. 15

POWER FACTOR IMPROVEMENT

The 'black box' provided represents and inductive device which will be used in a variety of situations in which different values of its power factor will be required. A switched variable capacitor is available and you are required to provide a chart showing the variation of power factor made possible by varying the capacitance from 0 to 28 μF. when the device is used with a 115V 50 Hz supply. The connectinn of the power factor meter is indicated



Requirements and Assessment

1. Measure the power factor of the device alone and when the switched capacitor is connected and varied up to 28μF. At each increment tabulate I, V, power factor and actual power.

2. Prepare a chart in graphical form which presents the discovered information in a way which will be acceptable for duplication and supply to customers.

3. Prepare an accompanying illustrated note for the chart explaining the main cause of poor power factor, the benefits of improving it, the method of doing so, the effect of using too high a capacitance and why it is more economical to increase the power factor to (say) 0.96 lag rather than 0.99 lag.

Circuit arrangement	5
Table	15
Accuracy and completeness of information	5
Presentation	20
Note Information	15
Presentation	10
	70

LABORATORY ACTIVITY NO. 15 (Notes to Teachers)

POWER FACTOR IMPROVEMENT

Usually little is asked of students at this early stage of acquaintance with the topic beyond repetitive simple calculations and drawing phasor diagrams, based on measurements made, which could almost equally well(and probably more quickly) be based on given figures. There is obviously potential value in using the equipment involved but this can be obtained in a more interesting problem-based situation such as is offered here. This is another example of an easily made transformation of a routine laboratory exercise into an activity which ensures that the concepts involved are reinforced rather than being glossed over by undemanding instructions. Instead of academic report writing communication skills are required in a context typical of technician work in industry, but within the capacity of students at this level, given appropriate guidance.

Learning Objectives

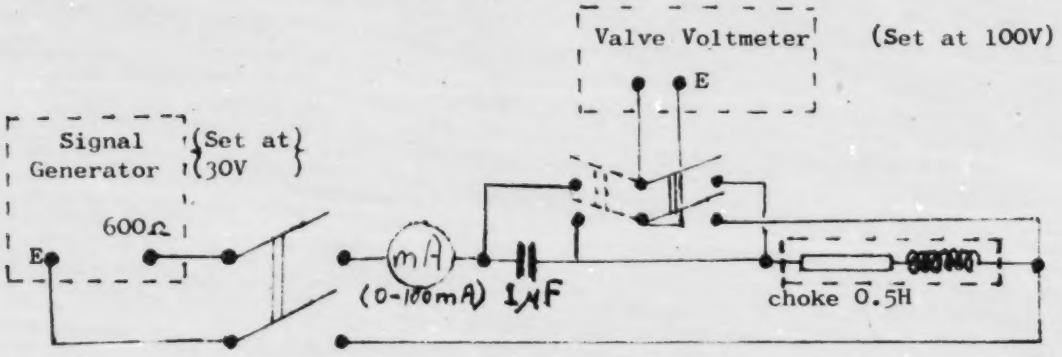
Comprehension:	Students will connect the variable capacitor to the device in a way consistent with the principles involved.
	Students will explain the key concepts involved in the topic and the practical consequences of them as indicated.
Application:	Students will use their theoretical knowledge of power factors to construct the table of values required.
	Students will construct a graph involving known techniques applied to a specified purpose.
Communication:	Students will demonstrate their ability to communicate technical information in graphical and verbal form in a way suitable for a particular group of users.
Laboratory Skills:	Students will use a power factor meter correctly.
Personal Qualities:	Students will identify with an imagined employer to add value to a product.
	Students will recognize the needs of users of the product in providing useful guidance.

Note: Teachers may have used a demonstration in class which would make the provision of the diagram unnecessary. The teacher concerned with communications should have given help to students on the presentation of information for'public relations' or customer use. The device used in the activity from which this is based was 100Ω , 0.35H. Other valves will lead to consequential changes in the activity specification.

LABORATORY ACTIVITY No. 16

EFFECT OF FREQUENCY VARIATION on an R-C-L SERIES CIRCUIT

The diagram illustrates a series circuit involving a capacitor and a choke to which an A.C. voltage of different frequency can be supplied by a signal generator. The p.d. across the two circuit components can be measured by a suitable voltmeter using a double pole change over switch. You are asked to investigate the effect on the p.d. across the capacitor and the choke of varying the frequency of the supply to provide the basis for subsequent theory.



Requirements and Assessment

1.	Check that the circuit is correctly connected and that the stated ranges have been selected Set the generator voltage to zero, close the DP switch and adjust the frequency to 140 Hz and adjust the output voltage to 5V. Record and tabulate the p.d. across the capacitor and the choke, the circuit current and the frequency Repeat this for frequency increments of 30 Hz up to 440 Hz taking extra measurements as needed to establish any key values made apparent from the graph described at 2 below.	Table of Values	10
2.	Concurrently plot a graph of the two measured p.d., the supply voltage and the current on a common frequency base.	Graphs	15
3.	Plot a graph of total resistance, inductive reactance, capacitive reactance and total impedance on a common frequency base.	Table of Values Graphs	10 15
4.	Describe in about 200 words what has been observed and what might be its practical consequences.	Description and comments	20
			70

LABORATORY ACTIVITY No. 16 (Notes to Teachers)

EFFECT OF FREQUENCY VARIATION ON AN R-C-L SERIES CIRCUIT

This is another example of the way in which an 'experiment' usually carried out to confirm theory can be easily converted into a much more electrifying(!) experience if it precedes theory and appropriately different demands are made on students. By concentrating the attention on observed phenomena rather than on a known theory the important element of surprise is retained and the level of comprehension which will accompany subsequent theory is enhanced.

Learning Objectives

Knowledge:	Students will describe the phenomenon of resonance in the circuit provided.
Application:	Students will predict possible consequences of resonance.
Analysis:	Students will compare the variation of measured and calculated values to provide the basis of their descriptions.
Synthesis:	Students will relate together different observations and effects linked to resonance.
Communication:	Students will display information about different observations on a common graph. Students will verbalize a series of observed events.
Laboratory Skills:	Students will use the equipment provided so as to obtain the required information.

Note: The temptation to ask students to take the theory of resonance too far should be avoided; the laboratory activity is better able to establish understanding if it is not made too mathematical. Some students could find the ratio of resonant p.d. supply voltage and be asked to consider why the ratios are not higher still but in general such consequential issues are more useful in a later class discussion.

LABORATORY ACTIVITY No. 17

CHANGING ALTERNATING CURRENT TO DIRECT CURRENT

There are many devices (or parts of them) which demand d.c. but which use a.c. as their initial source. This activity involves different ways of doing this which will be studied in theory later. It is important to observe carefully the results achieved in each case and to associate the results with the circuitry involved. Consider the advantages and disadvantages of each circuit.

Requirements and Assessment

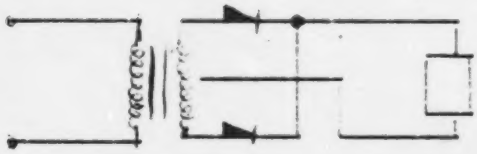
1. Use an oscilloscope to observe the wave form of the p.d. across the load in each of the following circuits. Sketch these wave forms and associated circuits.

Waveform sketches	
(a)	5
(b)	5
(c)	5
(d)	5
(e)	5
(f)	5

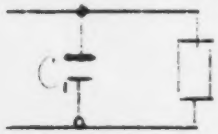
(a)

(b) as (a) except

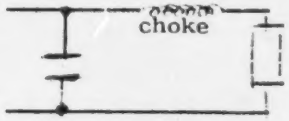
(c)



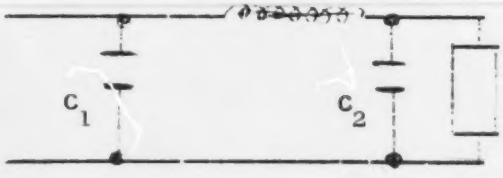
(d) as (c) except



(e) as (c) except



(f) as (c) except



carried forward 30

		Brought forward	30
2.	Compare 1(b) and 1(c) and comment on the value and limitations of these results in practical applications	Comments	10
3.	Compare in turn 1(d), 1(e) and 1(f) with 1(c), and describe the differences and discuss the value of these circuits.	Descriptions	15
		Comments	15
			70

LABORATORY ACTIVITY No. 17 (Notes to Teachers)

CHANGING ALTERNATING CURRENT INTO DIRECT CURRENT

Another example of guided concept building and discovery which is of much greater value to students, and teachers, if carried out before 'theory' than an 'experiment' to 'verify' theory can be. The terms 'rectification' 'half-wave', 'full-wave', 'smoothing' etc. are avoided at this stage, the subsequent association of the terms with experienced phenomena being much more meaningful than the text-book sequence of learning definitions and later trying to give meaning to them.

Learning Objectives

Knowledge:	Students will reproduce the waveforms corresponding to half-wave rectification and full-wave rectification with various degrees of smoothing. Students will recognise the circuitry associated with simple rectification.
Application:	Students will assess the usefulness of rectification in practical application.
Analysis:	Students will compare the results of the rectifying and smoothing circuits used and differentiate between their main features.
Laboratory Skills:	Students will connect and adjust an oscilloscope to give desired information.

Note: The choice of ratings for the double-wound transformer and the circuit components will be made by the teacher and should not be drawn to students' attention since it is the qualitative concepts which matter most at this stage. Students are learning important ideas by being made to look and think practically rather than theoretically.

PART 2

SECTION 2

PROJECT WORK

The word 'project' has been used to label so many activities in education and particularly further education that it may be foolhardy to claim that the term ought to be reserved for a particular kind of activity and that it is meaningless to use the word as a generally good-sounding term to cover whatever any user wishes to do. Nevertheless I do claim that the word does have a provenance in education for a fairly limited use and that the claims made for project work are seldom justified in practice because no consideration has been given to the nature of the process involved.

Projects are often proudly exhibited for approval which are either lengthy exercises of which the final result was known in advance and the assessment based on how close the students came to the teachers' stereotype, or are so open in content and treatment in the interest of a misunderstood student-centredness that students in fact gain very little in relation to the time spent which is transferable to situations they will encounter in future. In other cases the word project is attached to the top of a routine laboratory sheet or workshop exercise simply becuase it is a fashionable label to use. It is a familiar experience to be shown examples of 'project work','experiments', 'assignments' and'investigations' which are recorded and assessed separately only to find neither the teacher or his students can give any reason why a particular activity has been put into one category rather than another, except for the fact that 'projects', 'assignments', etc. were required to be carried out in the course so something had to be attached to each label. The question can be asked 'why have such different labels if the differences are so little?' but for answer one seldom obtains more than a puzzled frown.

A clear distinction between these learning activities is offered here. This has been discussed in many teachers meetings in England and Wales in the last few years and has met with a general approval and welcome which has reflected the support of those who have used student-centred activity-based learning situations from conviction rather than from obligation, and the relief of those who would have been looking for a way through the current jargon.

It may be that others have 'definitions' of these labels which they claim to be equally or more valid and which provide useful distinctions between the activities described which enable the aims of each to be equally well or better achieved. If so I will not quarrel with them for their motives have been the same as mine and their achievements are likely to be of the kind I would applaud. My quarrel is with the indiscriminate use of the labels which is the result of a failure to consider the educational aims and specific objectives which can be achieved by different learning processes embodied in different sorts of activities. The main theme of this collection of papers is that if it is desired to provide programmes with a range of aims covering knowledge, material and other skills and personal qualitie (as TEC has firmly stated), then it is necessary to identify objectives for this range of aims, and it is inevitable that a variety of learning experiences will be needed to achieve those objectives. The different contributions which each type of learning activity can make is a consequence of its own special nature and of the processes involved and these need to be identified if their value is to be gained by design rather than by chance.

The general term 'Laboratory Activities' has been used in the preceeding section to cover those activities which can be completed, apart from certain presentational matters, within the time usually available for a teaching period, say one to one and a half hours. They include investigations, discovery situations, straightforward problem situations (though not involving pre-determined solutions), industrial simulations again of a limited kind and of course some of the more conventional and well known laboratory activities which do serve a useful purpose. There is little point in labelling each of these short learning activities by a particular sub-classification since the nature of each is made quite clear to students in the task-related objectives which he meets under the eading 'requirements'.

The term 'Project' is more specific and there is real value in using the label to help students to associate a particular process with that word. It is indeed the process which distinguishes a project from other sorts of learning activity, and it is in the process that the transferable skills and personal qualities have their opportunities to be developed.

The process associated with project work can be derived from any sources from Dewey, to whom the origin of the process is often attributed to Open University work through the best of developments in primary education and elsewhere. The details vary according to circumstances but the project process is associated in all these cases to the solution of problems of a more or less complex kind which needs a systematic approach. The problems are not trivial needing only superficial thought or ones to which a single solution is possible. Nor are they problems for which the students involved already have sufficient knowledge to produce a solution. Given this start, which is often lacking in so-called projects, the process is able to provide for the achievement of educational aims of a most worthwhile kind. The project process can be represented by the following stages:

Stage 1 A problem is identified, or presented, or a difficulty or need is recognised.

Stage 2 The problem (or difficulty etc.), not being trivial, is given some consideration in order to clarify its nature and to identify missing information.

Stage 3 The knowledge (or skills etc.) which is needed before solutions can be attempted is acquired and organised in a relevant way.

Stage 4 With sufficient knowledge acquired possible solutions can be postulated. Since the problem is not trivial but is of a real-life kind there will not be a single inevitable solution.

Stage 5 The possible solutions are analysed and perhaps tried out, and the 'best' solution is selected.

Stage 6 The selected solution is implemented. Unexpected difficulties will call for modification of the plan and may even cause the selected solution to be reconsidered.

Stage 7 The problem is solved - the need satisfied or the difficulty overcome to the degree possible by those involved under the conditions operating. Whether or not the results are wholly satisfactory the process as a whole and the elements within it are transferable to new future problems.

These stages all need to be given their proper place by design, and not left to chance, if all that is claimed for project work is to be realised. The importance of this will be most apparent if some of those claims are examined. Take for example the list of abilities claimed to be developed in project work which was given in the notes for Guidance for the Ordinary National Diploma in Technology (Engineering). This list contains many valid claims but the note gives little if any guidance on the nature of project work and its particular way of substantiating these claims.

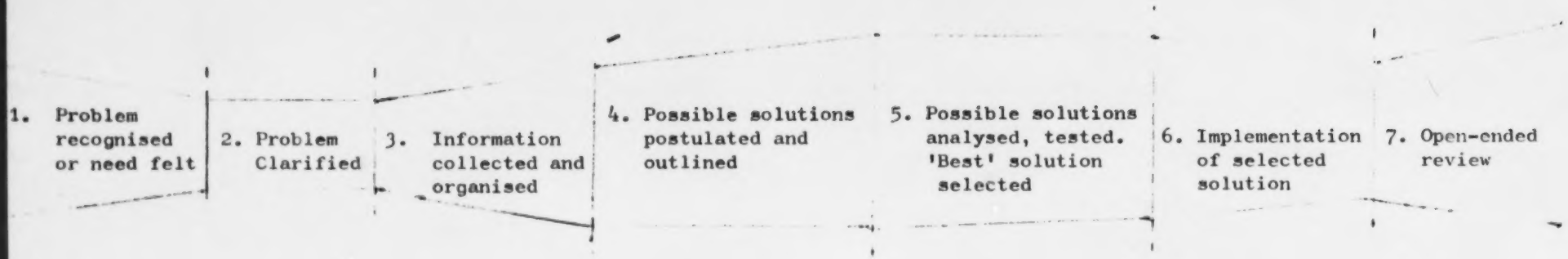
Ability	Form	Marks Act	Marks Poss
Knowledge and application	The content of knowledge required for the project and the success of its application		
Mental Skill	Manipulation of forulae etc. required by the project		
Physical skill	Quality of the physical manufacture and assembly of the project		
Analysis	Analysis of test results to produce a conclusion		
Synthesis	The ability to produce a whole and complete project from all the individual elements, taking into account unforeseen difficulties encountered		
Evaluation	Production of evidence for choosing the particular strategy for the project as opposed to others		

Translation and interpretation	The way in which the initial specifications are interpreted and then translated into a. a complete report b. theories c. hardware (if applicable)
Creativity	The quality of the creative aspective of the design to meet the given specification
Written communication	Quality of written content of the report
Graphical communication	Quality of graphical content of the report
Other abilities	As required
	Total 200

(Notes for Guidance OND Technology (Engineering))

The limitations of this list and the associated notes is exposed when it is used as the basis for assessment with marks possible and actual, The meaning of, say, 7/10 for synthesis or 5/10 for mental skill has never been explained to me by teachers concerned with the course nor more significantly, by students who have been given those marks. Some imaginative and useful work has been done in this course under the label 'Project Work' but much has been missed due to the absence of conscious structure and of a related assessment method.

If one re-examines the OND Technology (Engineering) list in the context of the stages of the project process described then they fall into place quite naturally. The following diagram illustrates how the abilities and qualities claimed relate to the different stages and how the thinking climate at each stage varies so as to involve what is often called convergent and divergent thinking at different times. Both ways of thinking are involved in real life and certainly in engineering.


1. Problem recognised or need felt
2. Problem Clarified
3. Information collected and organised
4. Possible solutions postulated and outlined
5. Possible solutions analysed, tested. 'Best' solution selected
6. Implementation of selected solution
7. Open-ended review

Translation
Interpretation
Self-awareness

Analysis
Discrimination

Knowledge
Interpretation
Personal
Relations with people and organisations

Creativity
Synthesis
Application

Analysis
Evaluation
Decision making

Physical Skills
Synthesis
Creativity
Teamwork
Leadership
Co-operation
Adaptability
Persistence
Work-rate

Evaluation
Generalisati
Translation
Communicatio

The diagram also illustrates why it is important that project work must be structured and controlled by teachers acting as consultants, and not allowed to be 'something which students do with minimum supervision' one of the worst definitions I have seen. The purpose of such control and supervision is not to shackle students and to make them do what the teacher wants but to ensure that they are not deprived of the opportunities for creative thinking as a result of their own desire to get on with the job. Most so-called project work I see falls into this trap and although often there have been valuable educational experiences in the process the amount of time spent has been out of proportion to the benefit. Students have often either been given, or have chosen, a 'project' and have moved with as much speed as possible to the implementation stage. It is very usual for students to answer when asked why they followed a particular design or idea, that it seemed the best thing to do, and that the teacher said that it was their project and they should do what they thought best. What then emerges is that nothing else was considered and really they were doing the first thing that came into their heads. These students were not in fact thinking for themselves, as the teacher honestly believed, they were being prevented from doing so by being allowed to do the first thing they thought of, which is not really thinking. Seldom does an outline of possibilities and an analysis of them exist and seldom have the opportunities for real problem solving been taken. The diagram illustrates how the result is a concentration on the convergent stage working towards a planned outcome. Such convergent processes are, naturally enough, prevalent in most engineering and science teaching where a body of knowledge involving facts, laws, principles and techniques has to be soundly established. But unless this body of knowledge is used in real-life problem situations such as can be simulated in projects and some other activities it is likely to be of little long term value. If the projects do not, by design, provide experience in problem solving techniques and provide unavoidable requirements to develop the transferable mental skills and personal qualities which are involved at the various stages then the value of the project may be far more limited than otherwise and not be an efficient use of students' time. The aims of a project involving the design, say, a pump or the design and manufacture of a page turning device for disabled readers can be made to embrace more than just that if long lasting educational considerations are built in. The students will probably never have to design a pump or whatever again and will forget the technical knowledge they acquire in doing so. But if they have been made to analyse and create by the synthesis of ideas to evaluate and decide between a variety of possibilities to reflect on the nature and validity of their decisions; in short to have become conscious of the processes by which they achieved their results, then they will have developed skills and qualities which will transfer without conscious effort of recall to their subsequent lives both at work and elsewhere.

The two examples which follow illustrate the approach to project work outlined above both in the way that the project brief is presented and in the way that the assessment is structured and weighted. It has been the theme of these notes that assessments must reflect both the aims of the activity and the process in which learning has taken place. This relationship is made very clear in the following examples and is amplified in some notes later.

The examples given are both of fairly short duration and are teacher-designed. These two characteristics are worth comment.

It is often assumed that a project is something that occupies a whole session and students talk of their project in the singular. The value of such a large time allocation if the activity is largely routine implementation has already been questioned. If it is accepted that the problem solving process is the key to project work and that it is the process which incorporates the long term benefits, then the more often that students are involved in the process the better. A long project even if well planned may involve using sources of information of a certain specialised kind only and once only. It may require students to postulate unobvious possibilities once only and to analyse their merits and decide between them once only. The implementation stage may well involve, unexpected difficulties and problems which themselves need to be solved but these tend to be treated as subsidiary issues which have to be unriddled by effective expedients in the interests of the main problem. This is, of course, of genuine value but the point is that the main problem solving process is consciously followed once and therefore not adequately reinforced in a variety of situations.

A belief in the value of the project process as a process leads to the desire to expose students to the opportunities, demands and challenges of the process as often as possible and it is likely that a number of short projects will benefit students much more than one long one.

The other characteristic deserving comment is that the examples given are teacher designed. Of course that is inevitable in these notes but there is merit in that approach, which needs to be stressed. Three arguments about teacher-designed projects are important. First the importance of the process as outlined above. It is easier for teachers to ensure that the brief given to students creates the necessary demands than for students themselves to do so for obvious reasons. However this is not an overiding argument and it is even more valuable if a student selected project is initially discussed and an agreed brief as in the following examples, including the weighting of assessments, is drawn up. This will forcus students' attention very effectively on the important stages and will avoid a great weakness of student designed projects which is that students usually choose to do something which they have a preconcieved solution for and really want the opportunity to implement it.

The second argument concerns the content of the project and this seems to resolve more positively in favour of teacher designed projects. Projects take up time which is always at a premium in further education. As has been argued earlier that time is often not well spent because important stages in the process have been neglected and a lot of time is spent in getting the job done. A different but equally disturbing inefficiency in the use of time which arises is due to the fact that in many cases the knowledge content has only a tenuous connection with the course of which the project is supposedly an integrated and integrating part. It must be remembered that an educational project is a learning activity and that each project should be germane to its course in the area of knowledge involved as well as developing the more generalised mental skills and qualities outlined. Many projects could equally well have been carried out in quite different circumstances without the special help of anyone

involved in the course being followed. I suspect if a student tells me that his project could have been done at work or in a suitably equipped club, that much of its value as part of his course has been lost by default. The project may have been highly motivating and have had a successful outcome but its relevance may not be sufficient to justify the time spent. It is, or ought to be, an important task for the teacher to ensure that the knowledge content of each project is sufficient in quantity and at an appropriate level and this, like the clarification of the process involved is usually better done in teacher-designed rather than student originated projects.

A third argument relates to industrial realism. Technicians do not in general choose to do particular projects in the way that research workers sometimes do. They will normally be constrained by an imposed brief within which to work. This need not restrict their creativity, indeed it can be claimed that more original work has grown out of restricting conditions both in art and engineering than when no limits are imposed.

These arguments lead to no dogmatic outcome but the risks of student originated projects, however motivating, being of little relevance and becoming production exercises are considerable and need to be consciously avoided by close control by teachers of the agreed brief and assessment scheme at the outset and need close supervision, as do all projects, to ensure that time is not spent ineffectively. The idea that projects are carried out by students with minimum supervision is, certainly at the level of technicians, one which leads to much poor project work. The need for supervision is not based on a desire to over structure students' work or to remove the scope for initiative and independent action but to ensure that these and other abilities are developed and that students are protected from their natural desire to get on and do the first thing that seems reasonable.

Projects are learning activities. Teaching is helping students to learn. In projects the teacher must carefully balance the need to help in structuring and insisting that vital stages are not by-passed, with the need to ensure that students imagination, creativity and other abilities are not limited by the teachers own preconceptions about outcomes. A project for which the teacher or student has a preconcieved ending is no project.

The Assessment of Project Work

The principles of assessment previously discussed enable the problems of assessment in project work to be overcome in a way which satisfies both teachers and students. The assessment must, as always, reflect directly and clearly both the aims of the activity and the learning process involved. Having identified the process involved and devised a situation appropriate to the course of study the assessment schedule is easily devised and the weighting given to each stage indicates clearly to students the relative importance of each. The great value of a programme of project work embracing several projects rather than one large one, is that the process is followed several times and the weighting of the various stages can be varied according to need, so that the different abilities are developed progressively.

The project team will need to allocate a total mark to each project according to their estimate of the demands expected to be made and the time allowed for completion. If the brief presented to students is structured to correspond to the process described and as exemplified by the following examples, then the assessment scheme is simply an exact parallel one. This is detailed on the reverse of each brief. The maximum mark is indicated for each stage so that students are clear about the weighting given to each. If the project is student or employer originated then a similar brief and assessment scheme will be drawn up by the teacher and student in consultation.

In the examples given an intermediate assessment based on a six point scale 0-5 is used since this has been found useful in practice. Obviously other methods of arriving at the mark for each stage could be used. In this method 5 is awarded for the highest standard and 0 for insufficient or very poor work. The rough average of these for each stage (intermediate weightings are within the teachers and students operating discretion) enables the mark awarded to be easily calculated as that many fifths of the maximum. Thus if the maximum for a stage is 25 a grade of 3 gives 15, and a grade of 4 gives a mark of 20. There is clearly an advantage in allocating maximum marks in multiples of 5. Fractional marks may be used.

The marks allocated should be recorded by stage as well as by project in a simple grid. For example:

Project Title	Stages						Project Totals
	2	3	4	5	6	7	
A	- / -	10 / 20	22 / 40	5 /	8 / 20	6 / 10	51 / 100
B	6 / 10	15 / 20	25 / 30	16 / 20	20 / 60	4 / 10	86 / 150
C	8 / 10	8 / 10	20 / 25	18 / 25	32 / 50	18 / 30	104 / 150
D	16 / 20	9 / 15	38 / 40	19 / 40	42 / 100	14 / 35	138 / 250
Stage Totals:	30 / 40	42 / 65	105 / 135	58 /	102 / 230	42 / 85	379 / 650

This record is more useful than simple gross marks just in the way that assessment at each stage is more valuable to students than a final one. Since each stage corresponds to the same general sort of activity (such as collecting and organising information) the stage totals tell a great deal about the sort of abilities and achievement of the students. This provides a form of profile which reveals that a student may have high imaginative and creative abilities but be less able to carry through his ideas. It will reveal that a student may be good at organising information and presenting paper reports but not of high practical value in demanding situations. These distinctions disappear in total marks and such marks have little educational value for students. The greatest value of assessments should always be that they contribute to the learning process by helping students to improve and develop in specific ways

A number of papers on project work and its assessment have been written in recent years. The approach advocated here owes a lot to these papers as well as to the work of a few innovatory teachers. The approach here is however

much simpler and more generally applicable than usual; it involves easily understood procedures and aims which both teachers and students can adapt readily and recognise as valid; it involves simple briefs which nevertheless incorporate a lot of initial thinking, it involves simple and unsophisticated records; it provides feedback for students and teachers on the achievement of agreed task objectives, real help in the learning process and far more valid and reliable assessments for record and certification purposes.

PROJECT EXAMPLE No. 1

THE WANKEL ENGINE No. of Students: 1 Total Time: 10 hours

Stage 1 The Problem. You are required to give a talk on this topic to the course members on ..... at ..... . You will have a maximum of 20 minutes which is to include any audience participation you may plan to involve.

Stage 2 Consider the problem by reviewing your existing knowledge of the subject and your previous experience of giving talks.

Stage 3 Collect and organise information on the subject. Identify useful sources of information and classify the information gained e.g. historical, popular description, design details, etc. Note the source of each item.

Stage 4 Consider possible solutions to the problem. There are two matters for consideration:

(a) What is to be included in the talk
(b) How the material is to be presented.

Briefly outline three possibilities for each of these.

Stage 5 Select the best or preferred solutions after making a table (or otherwise) to show the advantages and disadvantages of the possible solutions identified. Give a short summary of the reasons for your selection.

Stage 6 Implement your selected solutions. Prepare the material and its presentation as decided with whatever modifications that become necessary due to unforseen developments. Negotiate with the audio-visual aids technician for presentational resources needed. Give the talk as required.

Stage 7 Review the activity. This should be very brief. Arrange the material already completed in a convenient way. Evaluate your talk under the headings (a) Content and (b) Presentation and review the decisions you made in Stages 4 and 5 in the light of hindsight.

The assessment schedule is overleaf. If you consider that the balance of marks should be changed discuss this with your project consultant.

PROJECT EXAMPLE No. 1

The Wankel Engine **Assessment Schedule**

Actual	63
Possible	80

Total Marks

The main aims of this project relate to the acquisition, organisation and communicational information and the assessment therefore reflects these aims.

Stage 2 **Initial Considerations** Unassessed

Stage 3 **Collecting and Organising Information**

Information from college sources 3
Information from external sources 4
Classification and Organisation 2
Overall grade for Stage 3 3

Marks	
Act	Max
15	25

Stage 4 **Possible Solutions**

Three content possibilities 2
Three presentation possibilities 5
Overall grade for Stage 4 4

Marks	
Act	Max
8	10

Stage 5 **Selection of Solutions**

Analysis of Content Possibilities 1
Analysis of Presentation Possibilities 4
Reasons for selection of content 2
Reasons for selection of presentation 4
Overall grade for Stage 5 $3\frac{1}{2}$

Marks	
Act	Max
7	10

Stage 6 **Implementation**

Preparation of Content
Key Points 3
Logical development 3
Preparation of presentation
Notes for talk 5
Aids to communication 5
Actual presentation 4
Overall grade for Stage 6 5

Marks	
Act	Max
25	25

Stage 7 **Review**

Arrangement of material 3
Self-evaluation 4
Overall grade for Stage 7 4

Marks	
Act	Max
8	10

Grades are 0 to 5. Actual Mark = $\frac{\text{Grade}}{5}$ x Maximum Mark
Each Stage is to be referred to The Project Consultant before proceeding.

PROJECT EXAMPLE No. 1 GENERAL NOTES

THE WANKEL ENGINE (or any other appropriate topic for different students)

This example is given as an illustration of the argument that many so-called or potential projects fail to achieve the aims associated with project work because the process is not made explicit and because the assessment does not relate to the aims of the process. The use of a talk to the class is not an uncommon device but the potential value is restricted if students do not consider both the possibilities for content (general interest, technical level etc) and for presentation (formal talk, use of hand-outs, illustrations, models etc). The project brief presented to students here is easily followed, presents clear task objectives, focusses on key tasks, makes the students think in varied ways of necessity and provides ample scope for individual responses. The assessment schedule is directly related to the tasks set and gives important supplementary information on the weighting of each stage.

Learning Objectives

Information:	Students will describe the Wankel Engine in such detail as is deemed appropriate. Students will assemble and classify information on the subject.
Comprehension:	Students will demonstrate their comprehension of the subject by making key points clear. Students will devise different ways of preparing a talk.
Analysis: Evaluation:	Students will analyse the possibilities devised and decide between them.
Communication:	Students will demonstrate techniques of verbal and other selected means of communication.
Independence:	Students will demonstrate the products of independent work and study.
Co-operation:	Students will co-operate with librarians, teachers, technicians and outside bodies to obtain information and resources.
Reliability:	Students will meet their scheduled committment.
Self Awareness:	Students will review their own performance in the light of their planning.

PROJECT EXAMPLE No. 2

VARIABLE SPEED DEVICE No. of Students : 2 Total Time : 40 hours each

Stage 1 The Problem You are required to design and build a model of a decide to convert a constant velocity rotational input into a rotational output which can be infinitely varied from $\frac{1}{3}$ to 3 times the input velocity. The input is 100 rev/min and the output power is 100W.

Stage 2 Consider the problem Write a brief introduction suggesting applications of such a device. What advantages and disadvantages are apparent at this stage when comparing infinitely variable and finitely variable speed converters?

Stage 3 Collect information about infinitely variable speed devices. Describe the principle of the various devices and classify the examples found according to principle of operation. Relate them to applications if appropriate. List or tabulate the advantages, disadvantages and particular characteristics of each class of devices.

Stage 4 Consider possible solutions for this application. Each member is to prepare outline designs for two different devices.

Stage 5 Select the best solution. Discuss the four outline designs and analyse their merits and drawbacks. Prepare a case as for a Development Manager for adapting your recommended solution.

Stage 6 Implement your solution Allocate the work of detail design and production of your model between yourselves by preparing a simple network analysis representing your estimate of the design-production-testing-modification-installation process. Keep a weekly log of how the work proceeds and make a record of how unexpected difficulties were met. Install and operate your device.

Stage 7 Review and Report Arrange all your previous material as indexed appendices to a report of about 1000 words evaluating the design and operation of the device. Make detailed recommendations for changes which would be necessary for a production prototype

PROJECT ASSESSMENT VARIABLE SPEED DEVICE MARKS

Actual	188
Max	300

The main aims of this project are related to the acquisition of information and its application. The application gives opportunities for originality and creativity and for the systematic organisation of the work on a co-operative basis.

Stage 2 Initial Thinking

		Marks Act	Max
Brief introduction	2	4	10

Stage 3 Collecting and Organising Information

		Marks Act	Max
Principles of devices	2		
Classification	2		
Advantages, Disadvantages etc	3		
Overall Stage 3 Grade	2	12	30

Stage 4 Possible Solutions

		Marks Act	Max
Outline design 1	4		
Outline design 2	2		
Overall Stage 4 Grade	3	30	50

Stage 5 Selecting 'Best' Solution

		Marks Act	Max
Analysis of four outline designs	3		
Case for selection	3		
Overall Stage 5 Grade	3	24	40

Stage 6 Implementation

		Marks Act	Max
Network Analysis	2		
Allocation of Work	4		
Design	4		
Production	2		
Difficulties	4		
Log	5		
Installation and Operation	4		
Overall Stage 6 Grade	4	112	140

Stage 7 Review and Report

		Marks Act	Max
Arrangement of Material	1		
Evaluation	1		
Recommendations	0		
Overall Stage 7 Grade	1	6	30

Grades are 0 to 5 Actual Mark = $\frac{\text{Grade}}{5}$ x Max Mark

Each Section to be referred to Project Supervisor before proceeding.

PROJECT EXAMPLE No. 2 GENERAL NOTES

VARIABLE SPEED DEVICE

This is an example of a more 'technical' project of a familiar kind in which design and manufacture are involved. However familiar the content the advantages of the presentation of the project brief and the assessment schedule in stages corresponding to the project process will be evident. It is not left to chance that students relate their project to industrial situations, or consider other methods than the most obvious, or evaluate the possibilities systematically. The structure ensures that the aims are achieved although naturally to a degree which varies with the students and of course with the quality of suspension.

Learning Objectives

Information:	Students will describe and classify rotary speed converters and their purposes.
Application:	Students will use the knowledge gained to solve the given problem in various ways.
Synthesis:	Students will propose solutions in the light of all the information and constraints involved.
Analysis:	Students will identify comparative merits of different possibilities.
Evaluation:	Students will decide on a preferred solution.
Communication:	Students will communicate their decision to a specified superior in an industrial situation. Students will assemble a variety of technical information and records into a coherent report.
Co-operation:	Students will implement their solution by joint planning and agreed work loads. They will work together to overcome unexpected difficulties.

PART 2

SECTION 3

ASSIGNMENTS

Like 'projects', 'investigations' and some other labels, the word assignment is used loosely and what is carried out under these lables is frequently indistinguishable. An argument has already been made for reserving the term 'project' to describe a substantial problem-solving and learning process. The terms 'investigation','discovery', 'experiment' and some others are usefully subsumed in the general term 'laboratory activities' which can cover a wide range of short activities with objectives limited by design to those considered to be more possible in activity-based learning situations. The kind of objectives which can be achieved by these activities has been exemplified earlier.

Teaching by assignment is yet another approach which has a well established history. It is a method which can achieve objectives of a different level to those achieved in laboratory activities. Teaching by assignment involves the assignment of parts of the syllabus to the student to be learned, according to specified criteria, by whatever method the student wishes. It is the method by which self-study and self-learning skills are most directly developed. It is strange that these skills and the self disciplines involved with them are so often claimed to be a major aim of education but nevertheless their acquisition is left to chance rather than consciously planned.

Some claims have been made for teaching by assignment on a large scale covering a whole course and enthusiasts have no doubt had considerable success. The resource implications are considerable in that learning material must be available in varied forms to suit various learners and perhaps to suit different sequential treatments. Frequent testing is also involved.

Most teachers concerned with technician education would instinctively reject teaching by assignment on a large scale for a variety of reasons. The inherent 'structure' of much technical study, the limitations of resources, the constraints imposed by timetables especially in part-time courses and other reasons would be given. The main objection consistent with the main argument of these pages is that for the range of aims and corresponding objectives which are to be achieved in technician programmes no one or two teaching-learning methods will suffice; not lectures or lessons or projects or activity methods or assignments. Each method has different purposes and if assignments are used in a limited but planned way they can make a unique contribution to the achievement of programme aims.

If most technical subjects do not readily lend themselves to teaching and learning by assignment on a large scale it is nevertheless probable that most subject contain topics which are eminently suitable for this approach. The specification of the content of units in the form of learning objectives enables such topics to be identified fairly easily. It will probably be sufficient if in most units one or two topics are selected, by identifying a related group of objectives. The criterion for selection should be that the source and sequence of acquisition of the knowledge involved is

unimportant so that the students are not penalised if they choose to learn in a particular way. Only the end performance is specified so that individual approaches to learning can be developed.

An implication of this is that students should not be supervised closely or at all in assignments although clearly in the early stages guidance in self learning skills will be needed. It should not be assumed that these skills will inevitably be acquired by trial and error or trial and success. Similarly the extent to which students are directed to particular references on other sources will diminish as their ability to find and use such sources develops.

Another important implication of assignment methods is that the expected performance of the students must be specified very clearly. Once again the objective must be directly related to the assessment. The easiest way to do this is to test the acquisition of the knowledge involved in a formal test item either independently or as part of a regular phase test. The actual test question, or a close outline of it, should be given at the time the assignment is set since this is the most unequivocal way of making the students task clear to them. Without this students are likely to misinterpret either the level or scope of the knowledge expected to be acquired. With this foreknowledge their motivation is dramatically increased and the achievement of the aims relating to self learning skills is more likely.

The assessments given to students in tests which end assignments should be recorded separately from other assessments because they provide different information about students corresponding to the aims of assignment methods. Although the objective perceived by the student will be in the knowledge area and the test item may differ little from other knowledge tests (except in being known in advance), the process by which that knowledge has been gained is of particular value and involves educational objectives perhaps not directly perceived by students.

The teacher does not say to students'This is to assess self-learning abilities', he says something like 'This is in place of a couple of normal homeworks and will save time in class. As long as you can answer this question satisfactorily on the day that's fine".

Given this approach assignments have a useful role to play which differs from other methods. The two following examples illustrate how simply assignments can be presented and how directly the assessment is related to the objectives presented to the student and in fact illuminates the requirements.

ASSIGNMENT EXAMPLE 1.

MATERIALS SCIENCE - CORROSION

You are assigned the following part of the syllabus to learn by any self-study methods you choose:

Syllabus extract: Chemical and electrolytic corrosion; simple electronic exchange; basic anode-cathode reactions; general tarnishing of metals.

You may find the following references useful:

(references to be given as desired)

The following points will be covered in the test items on this topic. Half an hour will be allowed for these.

1. The basic mechanism of the two types of corrosion.

2. Examples of engineering situations in which each type of corrosion occurs.

3. How corrosion due to these c uses can be controlled

   (a) in initial design;

   (b) in service.

4. A comparison of tin and zinc plating of steel.

ASSIGNMENT EXAMPLE 1 GENERAL NOTES

MATERIALS SCIENCE - CORROSION

This is taken from a pre TEC syllabus and so the extract given is not in objective form. If the topic is specified by objectives then it is easier to make clear to students what is expected of them, and if the objective fully specifies the standard to be reached and the conditions under which students will be tested then it may not be necessary to give such details of the test items as is done here. However the general practice in TEC standard units so far has not been to specify objectives fully and so the test details supply important target information for students.

Learning Objectives

Information:	Students will describe and differentiate between chemical and electrolytic corrosion. Students will give two examples of engineering situations in which each type of corrosion occurs.
Comprehension:	Students will describe one method of preventing each type of corrosion at the design stage and one method of controlling each in service. Students will discriminate between tin and zinc plating of steel by describing the effects of damage to each surface.
Independent Study Skills:	Students will work independently using self-selected sources to acquire the knowledge required.

ASSIGNMENT EXAMPLE 2

PHYSICAL SCIENCE - THERMOMETRY

You are assigned the following part of the unit to learn by any means you choose:

Syllabus extract: Comparison of gas thermometers, resistance thermometers, thermo-couples, radiation pyrometers. Principles of operation, fields of use, cost, convenience, accuracy.

References:

The test on this topic will consist of the following. The first item may be completed in your own time but the second is to be completed under test conditions in 20 minutes.

Item 1. Illustrate diagramatically the principle of operation of each device listed above.

Item 2. You will be required to complete a table comparing each device under the headings (a) fields of use, (b) cost, (c) convenience, (d) accuracy.

Final Request

I should be grateful for any comments which readers of this material would like to make.
I shall be equally grateful for any suggestions for additional learning material designed to achieve aims relating to those transferable mental skills and personal qualities which are essential to technicians.

J.K. Millington.
October 1976.

READING AND REFERENCE LIST

This list was prepared to accompany a series of three B.B.C. radio programmes titled "The New Developments in Technician Education" broadcast in October 1976 and to be repeated in December and January 1977. It provides a useful reference to publications which will enable readers to study techniques involved in curriculum design and implementation according to their own needs. Some of these techniques were practised in working groups at the WJEC courses out of which the present publication grew. Other publications in the list provide more general information or comment and some are useful in that they take different stances from the present writer.

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1. The creation of TEC was recommended by the Haslegrave Report (which was the response of the National Advisory Council on Education for Industry and Commerce to an invitation by the Secretary of State for Education and Science to review the national pattern and organisation of technician courses and examinations).

   DEPARTMENT OF EDUCATION AND SCIENCE/NACEIC
   Report of the Committee on Technician Courses and Examinations (HMSO 1969)

2. TEC has issued several documents giving details of its policy and procedures and offering guidance to colleges and teachers on the construction and submission of programmes.

   TECHNICAN EDUCATION COUNCIL - 76 PORTLAND PLACE, LONDON W1N 4AA.
   Telephone: 01-580 3050

   Policy Statement, June 1974

   Circular TEC 1/75: Introduction of Programmes leading to TEC Awards: planning information and provisional timetable.

   Circular TEC 2/75: General Procedures for Programmes and Awards.

   Circular TEC 3/75: A. Aims of Programmes leading to the Council's Awards.

   B. General and Communication Studies.

Circular TEC	4/75:	Sandwich Programmes leading to TEC Awards.
Circular TEC	5/75:	Information on colleges' Resources for Programmes leading to the Council's Awards.
Circular TEC	6/75:	Development of Aims of Programmes and Presentation of Unit Content.
Circular TEC	7/75:	Introduction of Programmes leading to TEC Awards: progress in the implementation of the provisional timetable.
Circular TEC	8/75:	Credit for Previous Attainment with particular reference to General and Communication Studies.
Circular TEC	9/75:	Practical Units in Full-time Programmes.
Circular TEC	10/75:	The Maintenance of Standards of TEC Awards.
Circular TEC	11/75:	Principles and Procedures of Validation.
Circular TEC	12/75:	Principles and Procedures of Assessment.
Circular TEC	13/75:	The Role of the External Moderator.
Circular TEC	14/75:	Health and Safety Content of TEC Programmes.
Circular TEC	15/75:	Level of Units.
Circular TEC	16/75:	Notes on submissions for the Validation of Unit-based Programmes.

TEC Guidance Notes

1. The Presentation of Educational Objectives in TEC Units.
2. Design of Programme Assessment Plans and Unit Assessment Specifications.
3. Criteria for Success in Units.

3. There have been a number of articles and letters in educational journals appraising the new developments in technician education. Recent examples are:-

IOLO ROBERTS Time to Reappraise the Technician Education Council. (Times Higher Education Supplement, 11 June 1976)

FRANCIS HANROTT A Tick for the TEC (Times Higher Education Supplement, 3 September 1976)

4. Useful studies of technicians and their training needs are:-

EAST ANGLIAN REGIONAL ADVISORY COUNCIL FOR FURTHER EDUCATION

Technicians within the Construction Industry:
recommendations for their education and training.
Report of a working party of the EARAC Building Sub-Committee.
(EARAC)

ENGINEERING INDUSTRY TRAINING BOARD

The Technician in Engineering. EITB Research Report No. 1.
(EITB 1970)

TRAINING SERVICES AGENCY

Technicians: a possible basis for a TSA programme.
A discussion document (TSA 1975)

5. General works which indicate the variety of approaches to curriculum planning include:-

MICHAEL GOLDBY, JANE GREENWALD, RUTH WEST (eds)

Curriculum Design (Croom Helm 1975)

ALAN HARRIS, MARTIN LAWN, WILLIAM PRESCOTT (eds)

Curriculum Innovation (Croom Helm 1975)

DAVID JENKINS AND MARTEN D. SHIPMAN

Curriculum : An Introduction (Open Books 1976)

HUGH SOCKETT

Designing the Curriculum (Open Books 1976)

LAWRENCE STENHOUSE

An Introduction to Curriculum Research and Development
(Heinemann 1975)

6. Books which emphasize the "objectives approach" are:-

R.F. MAGER

Preparing Instructional Objectives, 2nd Edition (Fearon 1975)

N.E. GRONLUND

Stating Behavioural Objectives for Classroom Instruction
(Collier-Macmillan 1970)

IVOR K. DAVIES

Objectives in Curriculum Design (McGraw-Hill 1976)

A.D. BAUME AND B. JONES

Education by Objectives (Nelpress 1974)

7. Detailed appraisals of the "objectives approach" are to be found in Stenhouse (above) and

MICHAEL MACDONALD-ROSS

Behavioural Objectives - A Critical Review

(Instructional Science 1973, No. 2. pp. 1 - 52)
This article is reprinted in abridged form in GOLDBY et al (above) and in full in LANCE DOBSON, TONY GEAR AND ADAM WESTOBY (eds) : Management in Education 2 (Ward Lock 1975)

DAVID HOGBEN

The Behavioural Objectives Approach : some problems and some dangers.

(Journal of Curriculum Studies 1972, Vol. 4, No. 1, pp 42-50)

8. Of particular use to lecturers in FE is a collection of papers from the Further Education Staff College.

JOHN RUSSELL AND JACK LATCHAM (eds)

Curriculum Development in Further Education (Coombe Lodge 1975)

9. The Principal of Bath Technical College has agreed to make available two documents prepared by his staff. (Requests should be accompanied by a stamped addressed envelope of C4 size).

BATH TECHNICAL COLLEGE - AVON STREET, BATH BA1 1UP

1. The Planning of TEC Programmes at Certificate Level.

2. Preparation of Technician Course Programmes:
Guidelines for the preparation of aims, objectives etc.

10. Advice on selecting patterns and methods of assessment is available in Russell and Latcham (eds) (above) and in :-

B. HUDSON (ed)

Assessment Techniques (Methuen 1973)

H.G. MACINTOSH (ed)

Techniques and Problems of Assessment (Edward Arnold 1974)

COOMBE LODGE REPORT

Assessment (FE Staff College, Vol 7, No. 13, 1974)

TECHNICAL JOURNAL

Objective Testing (February 1971, Vol 9, No. 1)
In-course Assessment (December 1971, Vol 9, No. 9)
Student Profiles (June 1972, Vol 10, No. 5)
Testing Practical Skills (April 1973, Vol 11, No. 3)
Oral Examining (May/June 1974, Vol 12, No. 4)

BRIAN KLUG

Pro-Profiles : a study of the uses of grading and profiles in academic assessment (National Union of Students 1974)

B.S. BLOOM, J.T. HASTINGS, G.F. MADAUS

Handbook on Formative and Summative Evaluation of Student Learning. (McGraw-Hill 1971)

11. A limited number of copies of a report written after a DES teachers' short course are available on receipt of a stamped addressed envelope (C4 size) from:

THE DEPARTMENT OF EDUCATION AND SCIENCE,
19 Talisman Square, Kenilworth, Warwickshire CV8 1JB.

DES Course N 476 - The General Component in TEC Certificate and Diploma Programmes.